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APOLLO SYSTEMS RELIABILITY

STATUS REPORT (U)

VOLUME II

SUBSYSTEMS RELIABILITY STATUS

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23 SEPTEMBER 1963

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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CLASSIFICATION CHANGE

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Scientific and Technical Information Facility

APOLLO SYSTEMS RELIABILITY

STATUS REPORT (U)

VOLUME II

SUBSYSTEMS RELIABILITY STATUS

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SECTION 12

INTRODUCTION

BACKGROUND

The reliability of the Apollo system is of paramount importance in attaining the mission assigned. To provide the most useful engineering management tool possible, the factors pertinent to reliability must be evaluated and interpreted to provide direct aid to the organizations responsible for the system. This volume is to become a unified engineering management compilation, combining the available data from NASA and contractor sources. Future editions will expand and complete the presentation of the reliability status as it is possible.

The variation in systems definitions, mission definitions, and program planning will require continued effort to assemble and present a coherent system report. Currently available system and mission definitions and data disagree in significant areas. It is the function of this report to make such a combination and to extract the significant trends and problems for individual attention. The present report is seriously limited in the completeness of the available information. However, established reliability problems are defined, and their significance is interpreted.

Formal center submittals do not now exist, and the material presented here is derived largely from contractor reports. Ultimate reliability apportionments will come from NASA sources, but the ones included are largely those of the contractors. ~~Adequate information~~ from centers and contractors will make possible a system documentation that will be directly useful in all Apollo areas. Major information sources to date have been the Apollo System Description, now seriously out of date, and NAA Quarterly Reliability Reports 62-557.

STANDARD DATA CODE

Table 12-1 illustrates the data code. The first 17 digits are the key to equipment identification; the remaining digits have other uses and are not specifically required for equipment identity.

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MISSION SYSTEM

1st and 2nd Digits

01	Apollo/Saturn I
02	Apollo/Saturn IB
03	Apollo/Saturn V
04	Apollo/Saturn -
05	Mercury
06	Gemini
07	Polaris

SUBSYSTEMS

3rd and 4th Digits

01	S-I
02	S-II
03	N-3
04	S-IV
05	Instrument Unit
06	Lunar Excursion Module
07	Service Module
08	Command Module
09	Launch Escape Module
10	Ground Operational Support System (GOSS)
11	Ground Support Equipment (GSE)
12	Lunar Logistics Module
13	S-IC
14	N-1
15	N-2
16	S-IVB
99	All Pertinent Subsystems

FUNCTIONAL SYSTEMS

5th and 6th Digits

01	Propulsion
02	Electrical Power
03	Structures
04	Environment Control
05	Guidance
06	Communications
07	Crew System
99	All Pertinent Functional Systems

FUNCTIONAL SUBSYSTEMS

7th, 8th, and 9th Digits

001	Engine Systems
011	Propellant Transfer and Pressurization
021	Vector Control
031	Engine Control System
041	Pneumatic Control System
051	Ignition
061	Ordnance
071	Propellant Utilization (Oxygen only)
081	Reaction Control
101	D-C Power Source
111	A-C Power Source
116	Power Sources (Exc. AC/DC)
121	Distribution Systems
131	Cabling
141	Interstaging
151	Lighting
201	Primary Structures
211	Basic Structures
301	Equipment Environment Control
311	O_2 Supply
316	Water System
321	Pressure Suit
326	Back Pack
331	Atmosphere Conditioning
336	Radiator (Crew)
341	Thermal Control System
346	Crew Mobility Systems
351	Survival Equipment
356	Recovery Aids
401	Rate Gyro Package
406	Control Accelerometer Package
411	Guidance and Control
451	Navigation and Guidance
456	Stabilization and Control
461	Power and Servo Assembly
501	Command Communications
511	Tracking
521	Audio/Visual
531	Telemetry
541	Instrumentation
601	Pilot
606	Navigator
611	Engineer
621	Personal Protection and Support
631	Waste Management
641	Food and Water
651	Personal Hygiene, Health and Comfort
701	C/O Equipment S-I, S-IC, N-1
706	C/O Equipment S-II, N-2
711	C/O Equipment N-3
716	C/O Equipment S-IV, S-IVB
721	Propellant Transfer and Storage
726	Pressurization and Storage
731	Transporter and Launchers
736	Ordnance Tower
739	Umbilical Drop System
741	Telemetry C/O Equipment
746	Command C/O Equipment
751	Instrumentation C/O Equipment
756	Tracking and Audio/Visual C/O Equipment
761	S/M C/O Equipment
766	Guidance Console
771	Mission Control
776	Computer Control
781	C/M C/O Equipment (Environment)
786	LEM C/O Equipment (Environment)
791	Near Earth Net
796	Deep Space Net
999	All Pertinent Functional Subsystems

COMPONENTS

10th, 11th, and 12th Digits

001	Engine
002	Fuel Feed
003	Oxidizer Feed
004	Solid Propellant
005	Fuel Tank
006	Oxidizer Tank
050	Fuel Transfer Ground
051	Fuel Transfer Flight Components
052	Oxidizer Transfer Ground
053	Oxidizer Transfer Flight Components
054	Fuel Pressurization Ground
055	Fuel Pressurization Flight Components
056	Oxidizer Pressurization Ground
057	Oxidizer Pressurization Flight Components
058	Fuel Transfer (Ground and Flight Half)
059	Oxidizer Transfer (Ground and Flight Half)
060	Fuel Pressurization (Ground and Flight Half)
061	Oxidizer Pressurization (Ground and Flight Half)
100	Fuel Discharge
101	Hydraulic Control
102	Servo Control System and Feedback, Hydraulic
103	Servo Loop
150	Missile Preflight Pressure System
151	Engine Purge Components (Flight and Ground)
152	Overspeed Trip
153	Engine Shutdown
200	Engine Fuel Purge
201	Engine Oxidizer Purge
202	Fuel Vent Valve Control
203	Oxidizer Vent Valve Control
204	Fuel Conditioning
205	Oxidizer Conditioning
206	Fuel Pressurization, Flight
207	Oxidizer Pressurization, Flight
250	Gas Generator Ignitors
251	Thrust Chamber Ignitors
252	Hypergol Start
253	Electrical Start
300	Primacord
301	Initiators
302	Explosive Bolts or Nuts
303	Retro Rockets
304	Pyrotechnic-operative cable-cutting Guillotines
305	Jettison Motor
306	Kicker Motor System
307	Manual Cable Cutter
350	Variable Flow Valve
351	Solenoid Controlled Valve
352	Servo Control System and Feedback (Elect.)
400	Batteries
401	Inverters
402	Voltage Measuring (Regulated) Supply
403	Fuel Cells
404	D-C Distribution
405	A-C Distribution
406	Connectors
407	Wire
408	Umbilicals
409	Shape Charge
450	Destruct Command Equipment
451	UDOP System
452	Television
453	SS/FM System
454	PAM/FM/FM System
455	PDM/FM/FM System
456	FM/FM System
457	PCM/FM/FM System
458	MISTRAM System
459	Azusa System
460	C-Band Radar
461	VHF System
462	UHF System
463	Intercommunications
464	S-Band System
465	Scientific Instrumentation
466	DSIF System
467	HF System
468	FM System
469	Remote Automatic Calibration
470	Emergency Measurement Detection
471	DDAS
500	Gyroscopes
501	Amplifier Demodulators
502	Accelerometers
503	Gyro-Stabilized Platform
504	Digital Guidance Computer
505	Guidance Signal Processor
506	Azimuth Alignment Package
507	Analog Control Computer
508	Command Receiver-Decoder
509	GN_2 Bearing Supply
510	Flight Sequencer
511	Inertial Measurement Unit
512	Optical Measurement Unit
513	Range Drift Measurement Unit
514	Guidance Computer
515	Power and Servo Assembly
516	Rendezvous Radar
517	Radar Altimeter
518	Attitude Reference
519	Rate Sensors
520	Control Electronics Assembly
521	Manual Controls
522	Displays and Controls
523	Power Supplies (Stabilization)
524	Coupling Display Unit
525	Scanning Telescope
526	Sextant
527	Inertial Reference Package
528	Three-axis Rate Gyro Package
529	Electronic Computer Assembly
530	Electrical Power Converter
531	Horizon Scanner
532	Longitudinal Accelerometer
533	Lights - Running and Flashing
550	LN_2 Cooler
551	Recompression O_2 Supply
552	Pressure Control, Atmospheric
553	Temperature Control, Atmospheric
554	O_2 System
555	Cabin Pressure Regulation
556	Superpressure Regulation
557	Gaseous Composition Control System
558	Radiator
559	Water-glycol Heat Transport Fluid Circuit
560	Cabin Thermal Control System
561	Suit Thermal Control System
562	Equipment Thermal Control System
563	Supplemental and Emergency Water Evaporativ
564	Portable Water Supply System
565	Cooling Water Supply System
566	Pressure Suit
567	Airlock
572	ODOP
600	Radiation Protection
601	Seating and Restraint
602	Decompression Protection
603	Urine Collection and Storage
604	Feces Collection and Storage
605	Personal Hygiene
606	Health

TYPICAL CODE EXAMPLE

DIGIT	CODE	EQUIPMENT
1, 2	03	APOLLO/SATURN V
3, 4	06	Lunar Excursion Module
5, 6	06	Communications
7, 8, 9	521	Audio/Visual
10, 11, 12	462	UHF System
13, 14, 15	052	Antenna
16, 17	23	NASA Operating Experience Record

Table 12-1

CODE S-STANDARD DATA CODE

607 Comfort
650 Propellant Conditioning
700 Pneumatic Control - Umbilical

999 All Pertinent Components

Cooling System

SUBCOMPONENTS

13th, 14th, and 15th Digits

001 Reactant Supply H_2
002 Reactant Supply O_2
003 Controls, Fuel Cell
004 Radiator (Fuel Cell)
025 Shackles
050 Receiver
051 Decoder
052 Antenna
053 Transponder
054 Camera
055 Transmitter
056 Signal Conditioner
057 Sensor
058 Transceiver
059 Belt Pack
060 Lunar Atmosphere Analyses
061 Gravitometer
062 Magnetometer
063 Radiation Spectrometer
064 Specimen Return Container
065 Rock and Soil Analysis
066 Seismographic Equipment
067 Soil Temperature Instrument
068 Radiation Detection Equipment
069 Recorder Electronics
070 Tape Deck
071 Headset/Microphone
072 Headset/Earphone
073 Multiplexer
074 Programmer
075 Electronic Switch
076 A/D Converter
077 Power Splitter
078 Signal Processor
079 Memory Device
080 LL Subcommutator
081 HL Subcommutator
082 Clock
083 Diversity Selector
084 EBW Firing Unit
085 Power Amplifier
086 Diplexer
087 IR Tracker
088 Tape Recorder
089 Stimuli Generator
090 Comparator
091 Wobbulator
092 Recovery Beacon
093 Extension Mechanism
094 Audio Control
095 Audio Center
096 Central Timing
097 Patch Panel
098 Commutator
099 Calibrator
100 AB-5K3 Gyroscopes
101 AMAB-3K3 Accelerometers
102 Air Pendulums
103 Gimbals
104 Platform Electronics Box
105 Resolvers
106 D-C Torque Motors
107 Wiring
108 Porro-prism
109 Electronics
110 Drum
111 Attitude Command Modules
112 Telemetry Register and Counter
113 Demodulators and Frequency Sources
114 Accelerometer Shapers
115 Switching Network
116 Discrete Signal Shapers
117 Power Supply and Power Sequence Circuiting
118 Digital Encoder
119 Leveling Device
120 Servo Electronics
121 Gain Change Program Mechanism
122 25-IRIG Gyroscopes
123 16-PIPA Accelerometers
124 Temperature Controls
125 Torque Motors
126 Platform Servo Amplifiers
127 Accelerometer Electronics
128 Gimbal-Mounted Preamplifiers
129 Power Supplies
130 Gimbal Angle Data Buffers
131 Gyro Torque Generator Amplifiers
132 Analog Display Buffers
133 Displays, Coupling
134 Optics
135 Mount Assembly
136 Optical Assembly, Sextant
137 Controller Assembly
138 Mode Select Panel
139 Parameter Select Panel
140 Angular Rate Indicator
141 Flight Director Indicator
142 Flight Director Control Panel
143 Manual Translational Controls
144 Manual Two-axis Rotational Controls
145 Manual Yaw Rotational Control
146 Manual Throttle Control
147 Display Panel
200 Control LN_2
201 Circulating System LN_2
202 Supercritical Storage System, O_2
203 Re-entry O_2 System
300 Pressure Suit
301 Food Storage, Preservation, and Cooking
302 Shaving
303 Washing
304 Dental Cleansing
305 Deodorizing
306 Laundry
307 Medical Supplies and Equipment
308 Sleeping Facilities
309 Recreation and Exercise Facilities

999 All Pertinent Subcomponents

SPECIFICATIONS AND MODELS

16th and 17th Digits

01 Reliability Functional Block (Hardware)
02 Environmental Functional Block
03 Event/Hardware Matrix
04 Event/Environment Matrix
05 Event/Time/Hardware Matrix
06 Functional Flow Chart
07 Success Diagram
08 Reliability Block Diagram
09 Reliability Diagram (Equation)
10 Drawings (Design, Assembly)
11 Parts Lists
12 Specifications
13 Reliability Allocations
14 Apollo Equipment Reliability Estimate
15 State-of-the-Art Equipment Reliability Estimate
16
17
18
19
20 NASA Failure and Maintainability Experience Record
21 NASA Failure Analysis Experience Record
22 NASA Corrective Action Experience Record
23 NASA Operating Experience Record

MISSION EVENTS

18th, 19th, 20th, and 21st Digits

0101 Crew Boarding Complete
0102 Arm LET
0103 Switch to Internal Power
0104 S-IC Ignition Cycle Start
0105 S-IC Mainstage
0201 Hold-down Release
0202 Maximum "Q"
0203 S-IC Cutoff
0204 S-IC Staging Complete
0205 S-II Mainstage
0206 LET Jettison Cycle Complete
0207 S-II Cutoff
0208 S-II Staging Complete
0209 S-IVB Mainstage
0210 S-IVB Cutoff
0301 Orbit Evaluation Complete
0302 System Checkout Complete
0303 S-IVB Ignition Cycle Start
0304 Translunar Injection Firing Program Complete
0305 Mission "Go" Decision
0306 S-IVB Mainstage (2nd)
0307 S-IVB Cutoff
0401 LEM/SM Interface Disconnect
0402 CM/LEM Docking Complete
0403 S-IVB/Instrument Unit Staging Complete
0404 System Checkout Complete
0405 First Outbound Midcourse Correction Programming Complete
0406 SM Mainstage
0407 SM Cutoff
0408 Second Outbound Midcourse Correction Programming Complete
0409 SM Mainstage
0410 SM Cutoff
0411 Initiate Watch Duty Cycle
0412 Complete Watch Cycle No. 5
0413 Complete Watch Cycle No. 10
0414 Complete Watch Cycle No. 14
0415 System Checkout Complete
0416 Third Outbound Midcourse Correction Programming Complete
0417 SM Mainstage
0418 SM Cutoff
0419 Lunar Injection Programming Complete
0420 Mission "Go" Decision
0421 SM Mainstage
0422 SM Cutoff
0501 System Checkout Complete
0502 Lunar Reconnaissance Complete
0503 Mission "Go" Decision
0504 LEM Crew Boarding Complete
0505 LEM/CM Disconnect Activated
0506 LEM/CM Separation Complete
0601 System Checkout Complete
0602 LEM Equiperiodal Orbit Injection Programming Complete
0603 LEM Landing Propulsion Mainstage
0604 LEM Landing Propulsion Cutoff
0605 LEM Midcourse Correction Programming Complete
0606 LEM Landing Propulsion Mainstage
0607 LEM Landing Propulsion Cutoff
0608 System Checkout Complete
0609 LEM Retro-Firing Programming Complete
0610 Mission "Go" Decisions
0611 LEM Landing Propulsion Mainstage
0612 LEM Landing Propulsion 2 Engine Cutoff
0613 Hover Maneuver Complete
0614 Translation Maneuver Complete
0615 Touchdown
0701 Launch Parameter Programming Complete
0702 System Checkout Complete
0703 Local Environment Survey Complete
0704 Crew Egress
0705 Crew Final Re-entry
0801 System Checkout Complete
0802 LEM Launch Propulsion Mainstage
0803 LEM Launch Propulsion Cutoff
0804 Midcourse Correction Programming Complete
0805 LEM Launch Propulsion Mainstage
0806 LEM Launch Propulsion Cutoff
0901 Initiate Angular Rate Control
0902 LEM Terminal Propulsion Ignite
0903 LEM Terminal Propulsion Burnout
0904 Terminate Range Rate Control
0905 Docking Maneuvers Complete
0906 Crew, Equipment, and Fuel Transfer Complete
0907 Trans-earth Injection Programming Complete
0908 System Checkout Complete
0909 LEM Staged
0910 SM Mainstage
0911 SM Cutoff
1001 System Checkout Complete
1002 First Inbound Midcourse Correction Programming Complete
1003 SM Mainstage
1004 SM Cutoff
1005 Second Inbound Midcourse Correction Programming Complete
1006 SM Mainstage
1007 SM Cutoff
1008 Initiate Watch Duty Cycle
1009 Complete Watch Cycle No. 5
1010 Complete Watch Cycle No. 10
1011 Complete Watch Cycle No. 15
1012 System Checkout Complete
1013 Third Inbound Midcourse Correction Programming Complete
1014 SM Mainstage
1015 SM Cutoff
1016 SM Staged
1101 CM Re-entry Attitude Assumed
1102 CM Re-entry Deceleration Complete
1201 Chute Mortars Armed
1202 Drogue Chute Deployed
1203 Main Chute Deployed
1204 Heat Shield Jettison
1205 Impact Attenuation System Deployed
1206 Touchdown
1301 GOSS Visual Contact
1302 Astronaut Recovery
1303 CM Recovery

SECTION 13

S-IC STAGE

S-IC Stage Description

RELIABILITY: **Allocated** ● **Predicted** o **Achieved** x

RELIABILITY

Subsystems	**Code**	**Center Submittal**			Percent of Unreliability Contributed	**Notes**
		Allocated	**Predicted**	**Achieved**		
Propulsion	01				1.6	1
Electrical Power	02				0.3	1
Structures	03				-	
Communi-cations	06				-	

Notes:

1. Engineering estimate for illustration.
2.
3.
4.

SECTION 13

S-IC STAGE
(CODE: 03 13)

DESCRIPTION

The S-IC stage (see Figures 13-1 and 13-2) develops 7,500,000 pounds of thrust supplied by five Rocketdyne engines with a thrust-to-vehicle weight ratio of 1.25. Four engines are gimbaled to provide a roll, pitch, and yaw control during powered flight. The maximum gimbal angle is ±6 degrees, including one degree for snubbing. The center engine is fixed and has no gimbal control.

The S-IC stage initially lifts the vehicle from the pad and raises it to an altitude of approximately 200,000 feet. The S-IC powered flight is approximately 150 seconds.

The S-IC stage will have four fins with an approximate area of 75 square feet. The fins will be attached opposite the outboard engines. Support and holddown for launch will be provided at four points (45 degrees between outboard engines).

CONTRACTORS

Prime Contractor - Boeing
Engine Supplier - Rocketdyne
Airframe supplier - Boeing
Communications Supplier - Collins Radio

MAJOR CONTRIBUTOR TO UNRELIABILITY

The F-1 engine is at present the major functional system contributing to stage unreliability due to engine rough combustion. A "fix" has been to baffle the injector. At present the staked copper sheet type baffle is not proving effective.

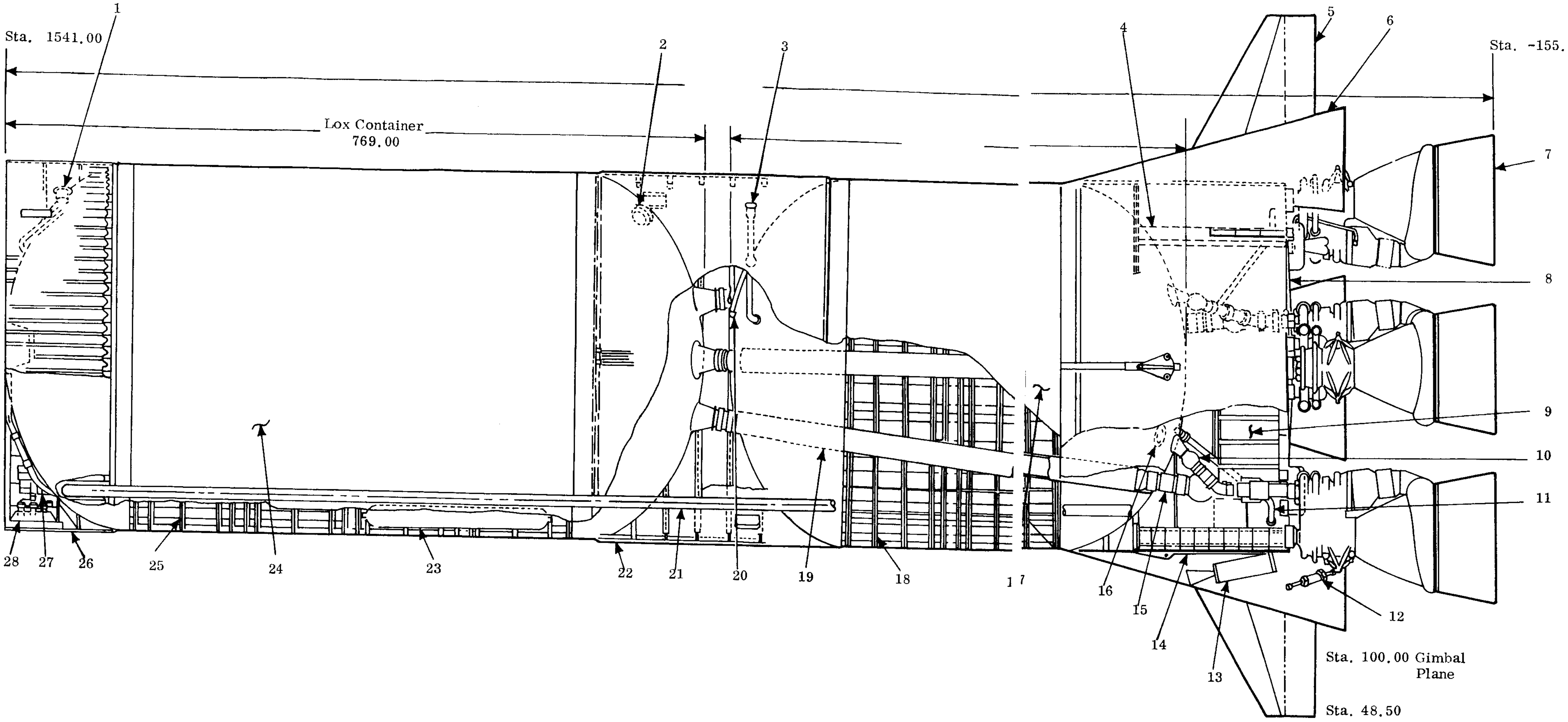
RELIABILITY TRENDS

When data is available the reliability curves on the opposite page will be discussed here.

RELIABILITY DOCUMENTATION

Subsystem: S-IC Module (Code 03 13)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X



1. LOX Vent
2. Emergency LOX Drain
3. Fuel Vent
4. Hold-down Post (4)
5. Fin (4)
6. Engine Fairing (4)
7. Hi-1 Engine (5)
8. Base Heat Shield
9. Center Engine Support
10. Fuel Suction Line (10)
11. Fuel Fill and Drain
12. Actuator
13. Retromotor (8)
14. Thrust Post (4)
15. LOX Suction Line (5)
16. Emergency Fuel Drain
17. Fuel Container
18. Slosh Baffles
19. Oxidizer Line Tunnels
20. Fuel Pressurization
21. Systems Tunnel (2)
22. Intertank Section
23. Helium Bottle
24. LOX Container
25. Slosh Baffles
26. Forward Skirt
27. LOX Pressurization
28. Instrumentation

Figure 13-1. S-IC Inboard Profile

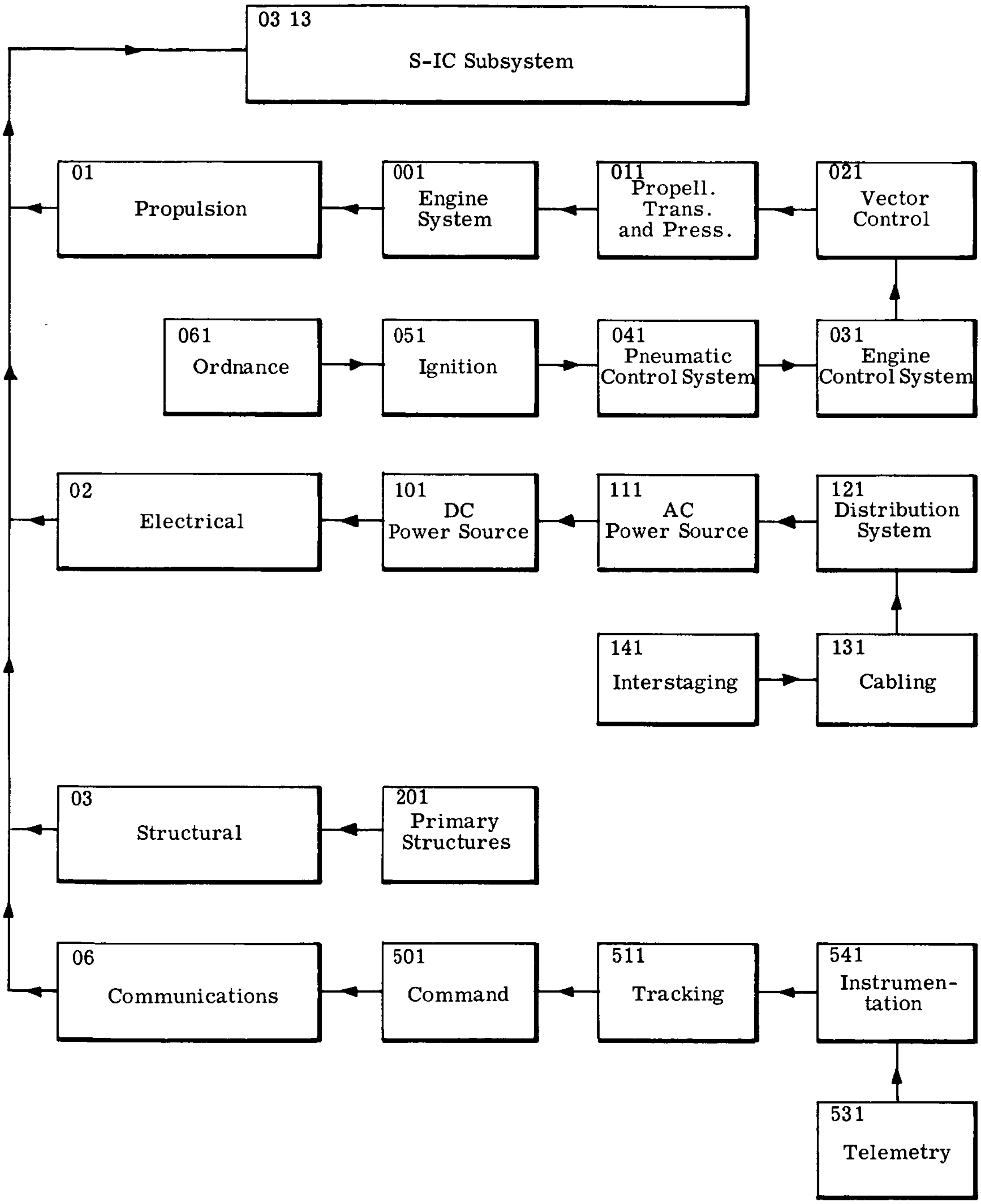
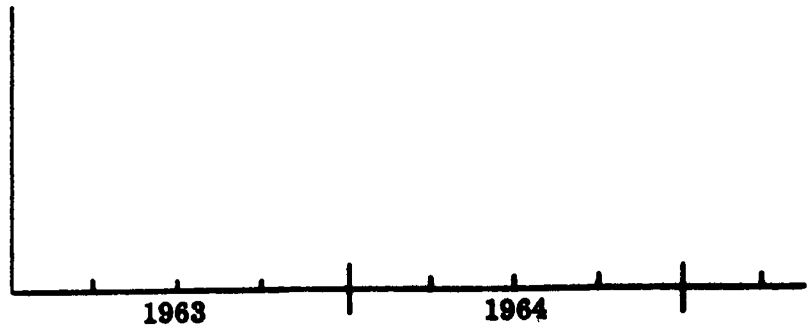


Figure 13-2. S-IC Subsystem Functional Block Diagram

S-IC Propulsion System

RELIABILITY: **Allocated •** **Predicted o** **Achieved x**



RELIABILITY

Functional **Subsystems**	**Code**	**Center Submittal**			**Industry**		**Notes**
		Allocated	**Predicted**	**Achieved**	**Best**	**Average**	
Engine System	001						
Propellant Transfer and Press.	011						
Vector Control	021						
Engine Control	031						
Pneumatic Control	041						
Ignition	051						
Ordnance	061						

Notes:

1.
2.
3.
4.

S-IC PROPULSION SYSTEM (CODE: 03 13 01) DESCRIPTION

FUNCTION

The propulsion system (see Figures 13-3 through 13-5) is activated after from 1.3 to 1.8 seconds by starting the F-1 gas generator. Ignition of the F-1 engine is accomplished in 0.5 second after gas generator ignition is detected. Transition from engine ignition to mainstage (90 percent thrust) occurs in 1.8 seconds.

Total obtainable thrust is 1,500,000 pounds. The weight mixture ratio is 2.25 ±2 percent.

The total propellant flow rate is 5700 gallons per second.

Fuel NPSH is 5500.	Pump inlet pressure is 45 psia.
LOX NPSH is 3381.	Pump inlet pressure is 65 psia.
Fuel tank pressure.	Preflight pressure is 28.5 psia.
LOX tank pressure.	Preflight pressure is 35.5 + 0.5 psia. -1.10 psia.

CONTRACTOR

Prime Contractor - Boeing
F-1 Engines - Rocketdyne

MAJOR CONTRIBUTOR TO UNRELIABILITY

The baffle on the injector of the engine is causing the greatest unreliability. Rocketdyne is employing a staked copper sheet baffle which is proving unreliable. It is expected they will use a stainless steel type baffle with film cooling or internal passages. This type of baffle is more reliable, but experience has shown that a great deal of erosion occurs at the tip of this type of baffle.

RELIABILITY TRENDS

When data is available, the reliability curves on the opposite page will be discussed.

RELIABILITY DOCUMENTATION

Functional Subsystem: S-IC Propulsion (03 13 01)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

1. Available information is from industry, contractors, and preliminary specifications. Center submittals have not been received.

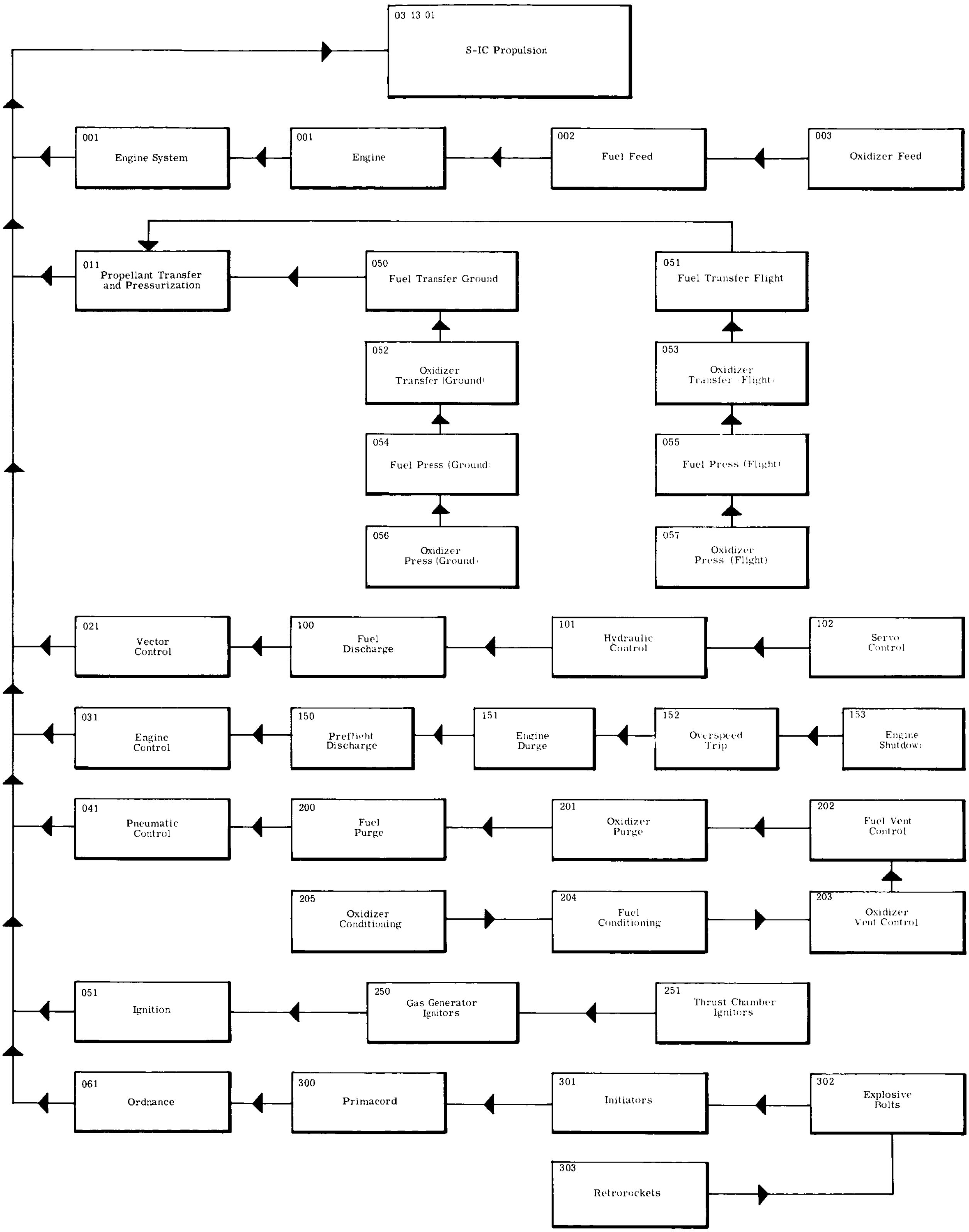


Figure 13-3. S-IC Propulsion System Functional Flow Diagram

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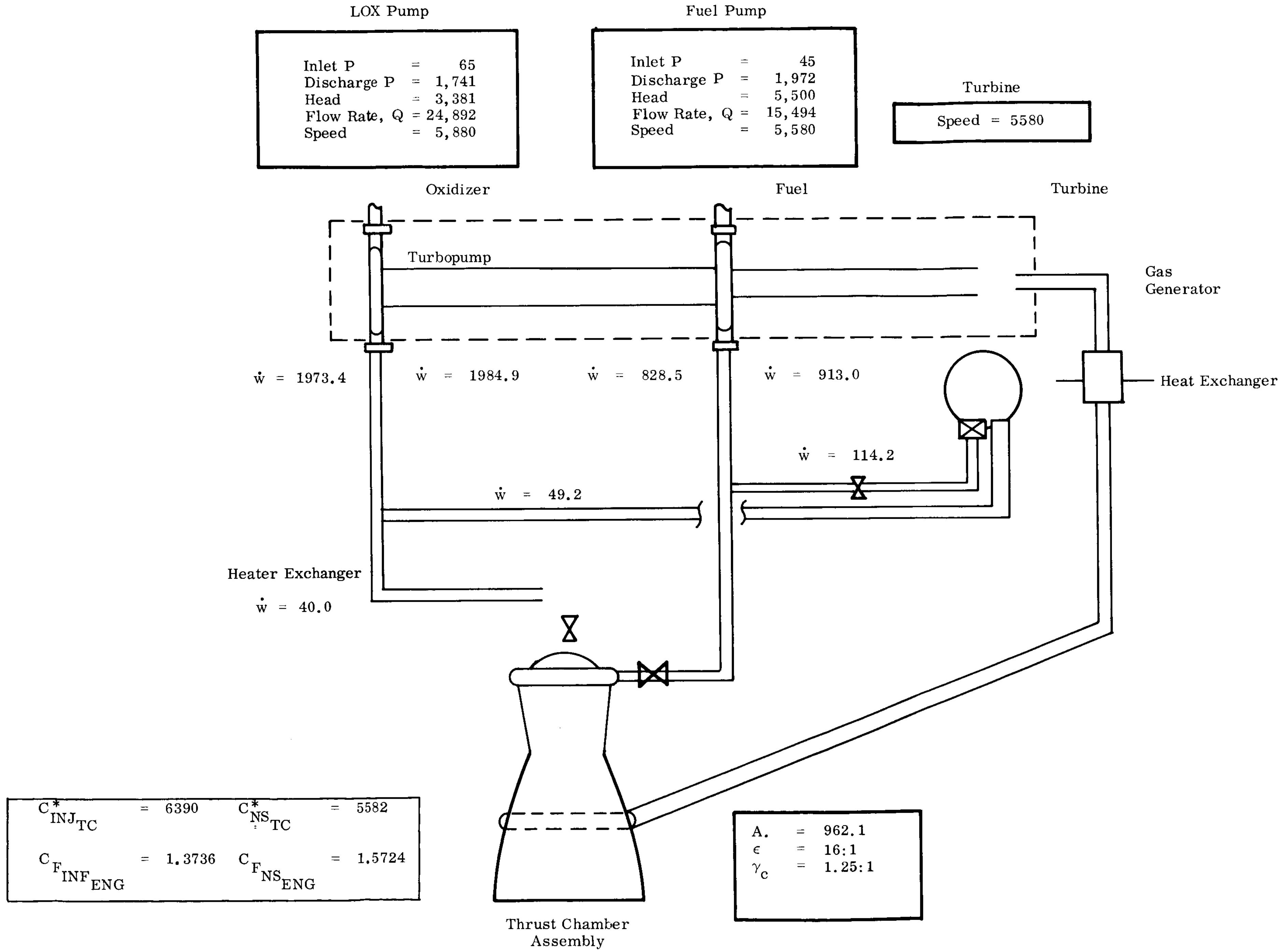

ENGINE

Thrust	=	1,500,000
Weight Mixture Ratio	=	2.25
Specific Impulse, Minimum	=	260
Total Weight Flow	=	5700
Atmospheric Pressure	=	14.696
Nominal Duration	=	150

Propellants
Liquid Oxygen: (MIL-025508-A)
Density 71.38 lb/ft^3
Temperature -297.4F

RP-1 (MIL-F 25576-B)
Density 50.45 lb/ft^3
Temperature 60F

Parameters, Symbol and Units

Thrust	F	lb	Density		lb/ft^3
Specific Impulse	I	I_{sp} sec	Characteristic Velocity	C	ft/sec
Pressure	P	psia			
Head	H	ft	Speed	N	rpm
Flow Rate, Vol.	Q	pm	Temperature	T	deg_2F
Flow Rate, wt.	W	lb/sec	Thrust Area	A	in.
Pressure Drop	ΔP	psi	Duration		sec.
Diameter	DIA	in.			

Thrust Coefficient	C_F
Expansion Area Rate	ϵ
Contraction Area	γ_c
Weight Mixture Rate	μ
Efficiency	η

Subscripts

INJ	Injector End
NS	Nozzle Stagnation
TC	Thrust Chamber

LOX — Hot Gases — Fuel — Orifice — Valve

Figure 13-4. Engine Theoretical Nominal Performance

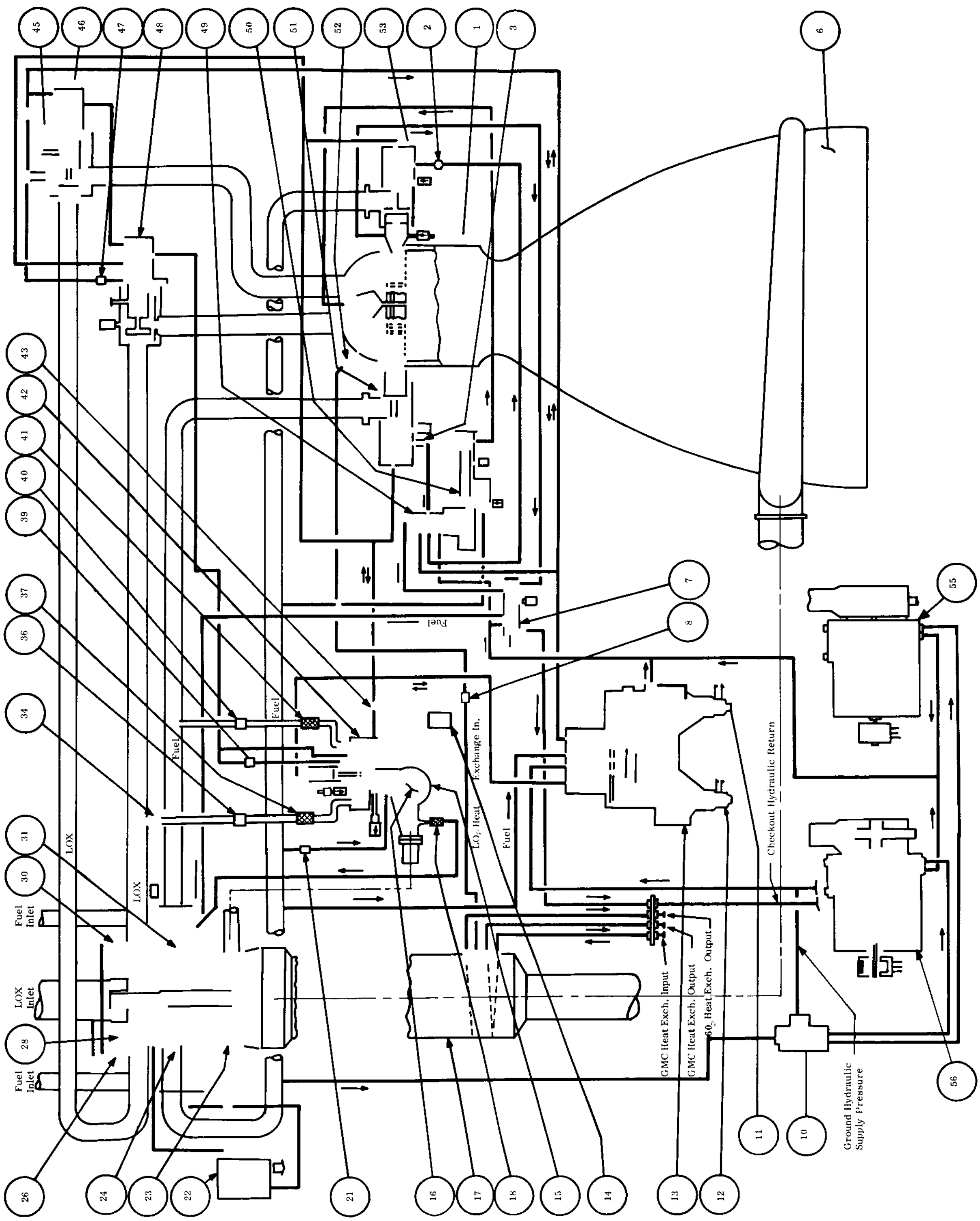

Figure 13-5. F-1 Engine System Outboard Schematic

S-IC Electrical Power System

RELIABILITY: Allocated ● Predicted o Achieved x

RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
DC Power	101						
AC Power	111						
Distribution Systems	121						
Cabling	131						
Interstaging	141						

Notes:

1.
2.
3.
4.

S-IC STAGE ELECTRICAL POWER SYSTEM DESCRIPTION (CODE: 03 13 02)

FUNCTION

These power systems are reasonably simple ones in which direct and alternating current needs are supplied by batteries and inverters as appropriate. Certain of the components are items of more or less standard use in the industry. The systems themselves, however, are not well defined in the information presently available, and their analysis has proceeded on the basis of synthesized systems which are assumed to be the most probable configurations. Since relatively subtle changes in the configuration and components used in such a system can have major effects on the reliability achieved, the values thus far derived are of low confidence.

The launch vehicle operations are of relatively short duration; the noise, vibration and possibly moisture environment are extreme and the line transients resulting from certain equipment operations are of considerable magnitude. These situations have an effect upon the reliability of the equipment in use. Accurate evaluation of these factors as applied to the specified Apollo hardware is not presently possible.

CONTRACTORS

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

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RELIABILITY DOCUMENTATION

Functional Subsystem: S-IC Electrical Power (03 13 02)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis	Not Applicable	Not Applicable
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

S-IC Communications

RELIABILITY: Allocated ● Predicted o Achieved x

RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Command	501						
Tracking	511						
Telemetry	531						
Instrumentation	541						

Notes:

1.
2.
3.
4.

S-IC COMMUNICATIONS (CODE 03 13 06)

FUNCTION

S-IC communications (see Figure 13-6) is equipped with measuring, signal conditioning, and telemetry systems for realtime transmission of the operating parameters of the vehicle. An emergency detection system is provided to allow a safe abort of the crew. A command destruct system is also provided in the event of mission abort.

CONTRACTORS

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

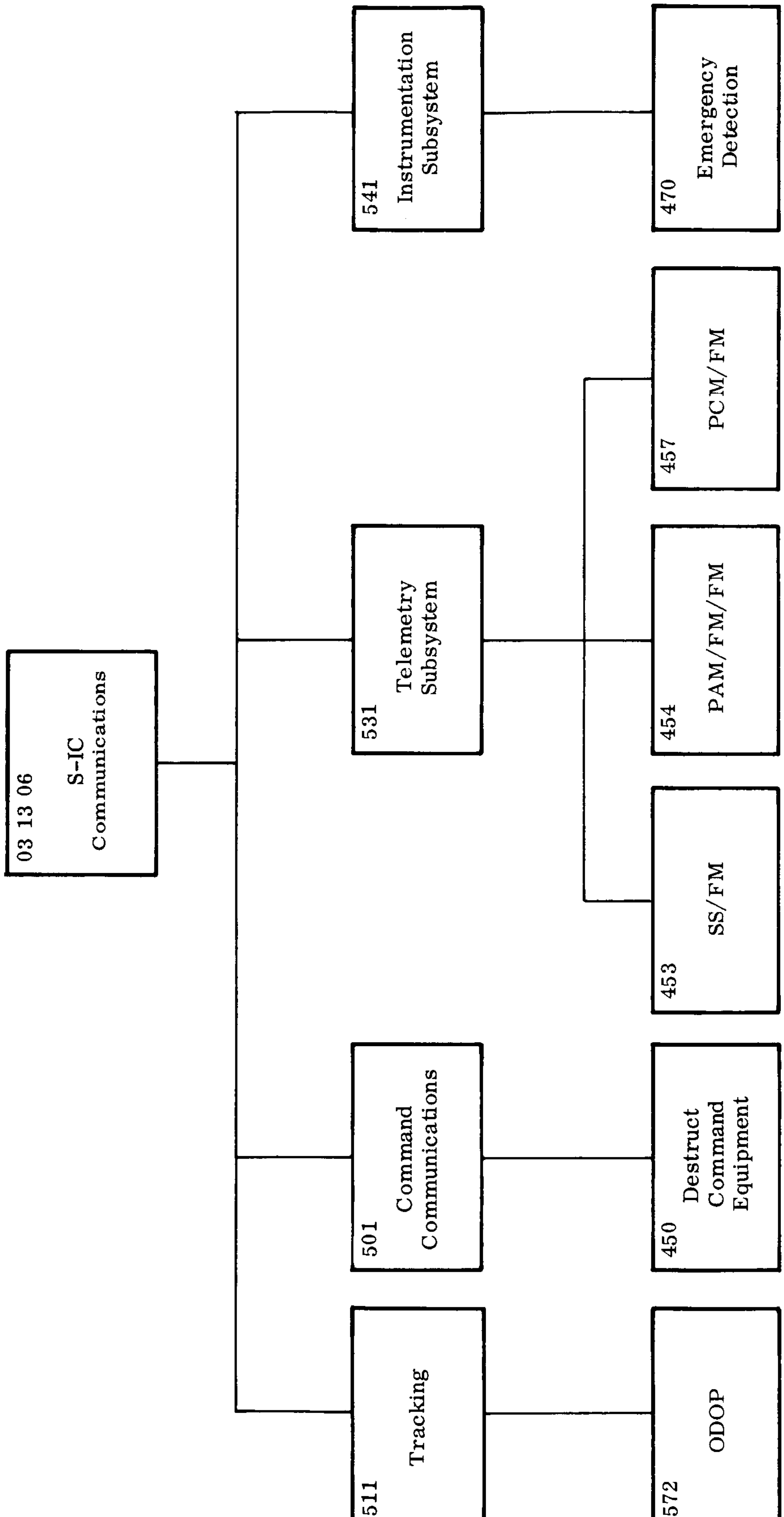

Figure 13-6. S-IC Communications Block Diagram

RELIABILITY DOCUMENTATION

Functional Subsystem: S-IC Communications (03 13 06)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis	Not Applicable	Not Applicable
7. Maintainability Plan - Flight	Not Applicable	Not Applicable
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

SECTION 14

S-II STAGE

S-II Stage Description

RELIABILITY: Allocated $\underline{\bullet}$ Predicted $\underline{o}$ Achieved $\underline{x}$

RELIABILITY

Subsystems	Code	Center Submittal			% of Unreliability Contributed	Notes
		Allocated	Predicted	Achieved		
Propulsion	01				0.4	1
Electrical Power	02				0.3	1
Structures	03				---	
Communications	06				----	

Notes:

1. Engineering estimate for illustration.
2.
3.
4.

SECTION 14

S-II STAGE
(CODE: 03 02)

DESCRIPTION

The S-II stage (see Figures 14-1 and 14-2) is the second stage of the Saturn C-5 launch vehicle and is designed for general earth escape and earth orbit payload applications. Mainstage propulsion is provided by five Rocketdyne J-2 engines.

The basic structure is conventional semimonocoque design with common insulated bulkhead separating the LOX container from the liquid hydrogen container, which is forward. The aft interstage structure will transmit launch loads from the S-IC stage to the aft skirt structure, the aft skirt structure will transmit thrust loads to the S-II stage body, and the forward skirt structure will transmit launch loads from the S-II stage body to the stage above. The conical thrust structure will uniformly transmit loads from the engine mount frame to the aft skirt structure.

Slosh baffles will be provided in each propellant container to control sloshing motion of propellants during flight by transferring absorbed slosh forces uniformly to the container structure.

CONTRACTORS

Prime - MSFC/North American Aviation
Engines - Rocketdyne

MAJOR CONTRIBUTORS TO UNRELIABILITY

RELIABILITY TRENDS

S-II data is generally inadequate for an appraisal report.

RELIABILITY DOCUMENTATION

Subsystem: S-II Module (03 02)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

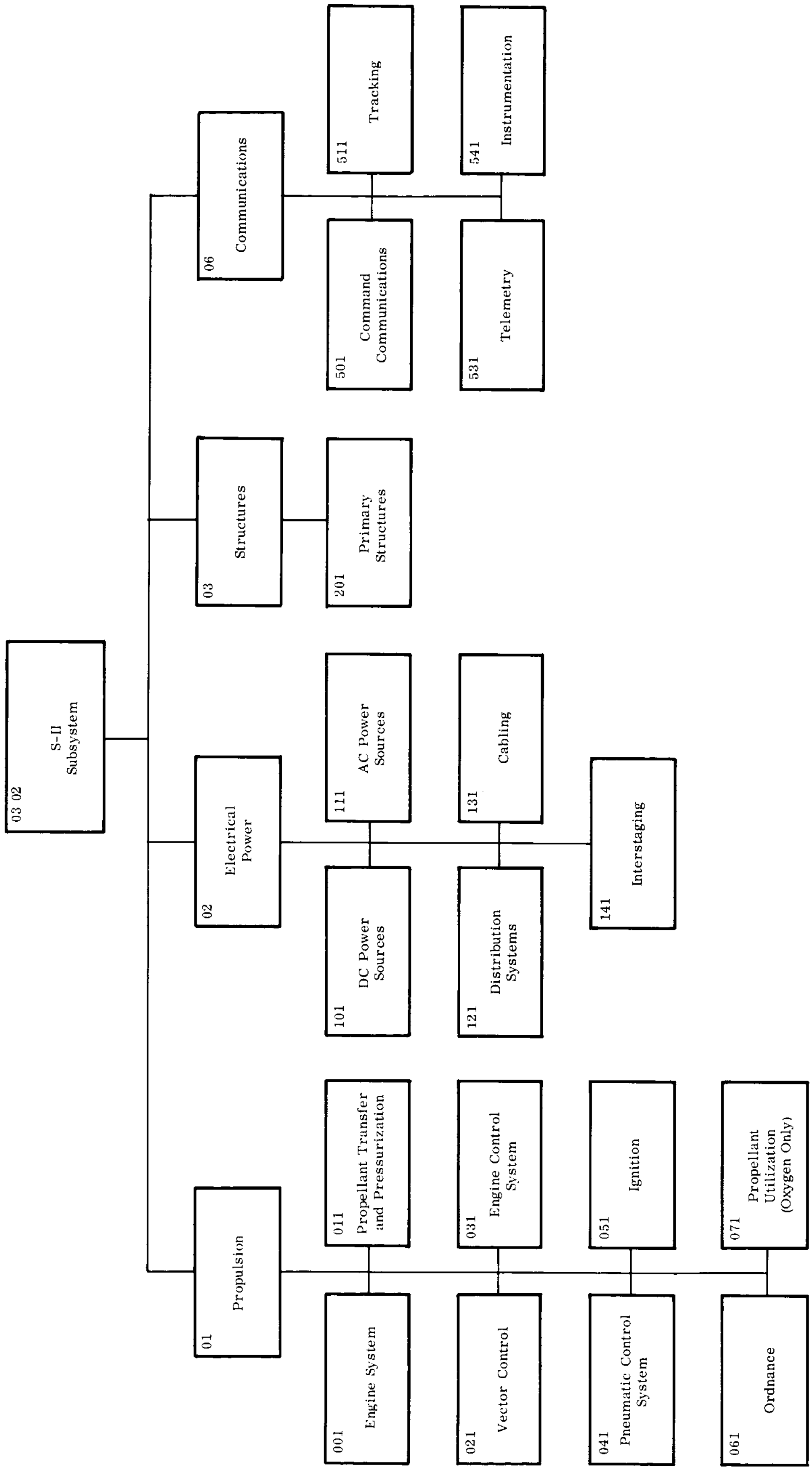

Figure 14-1. Subsystem Block Diagram

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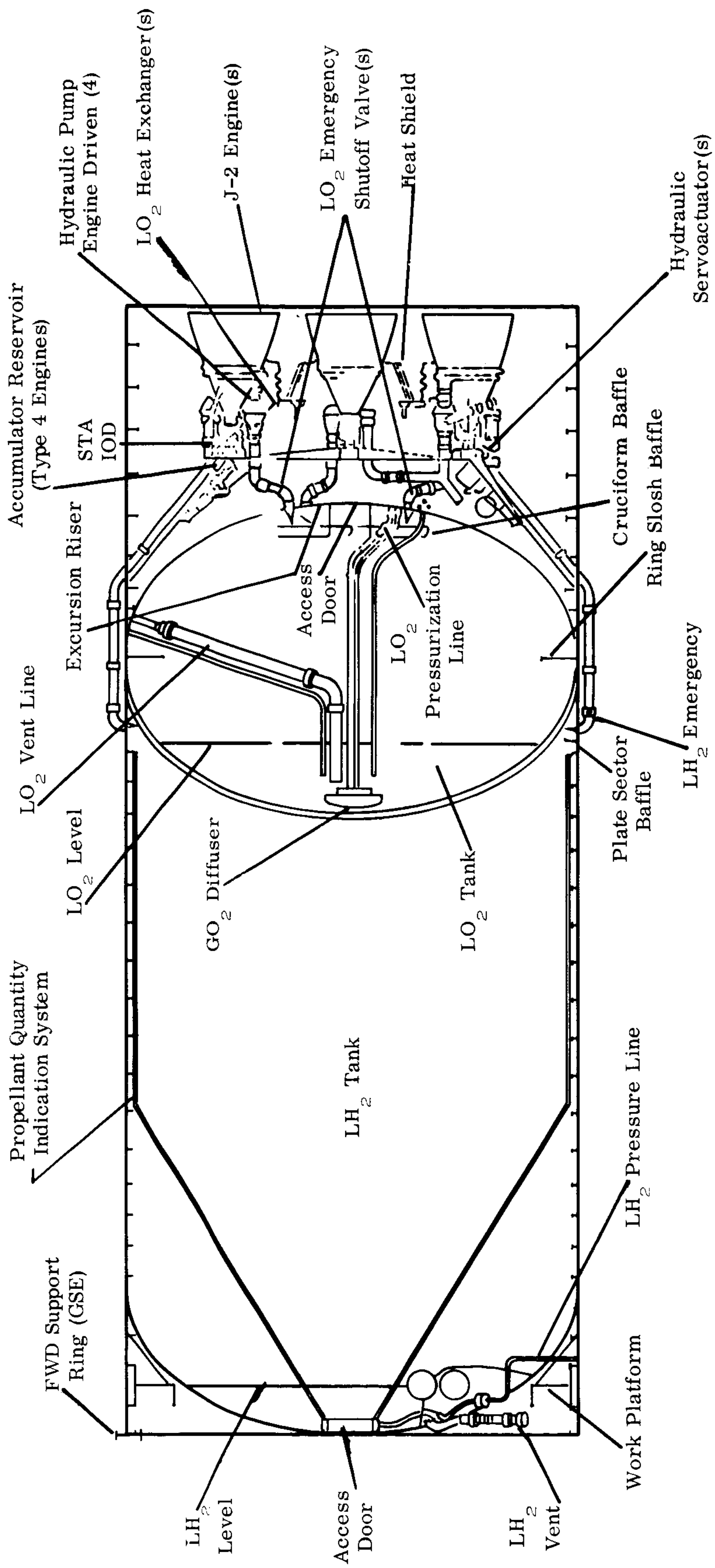
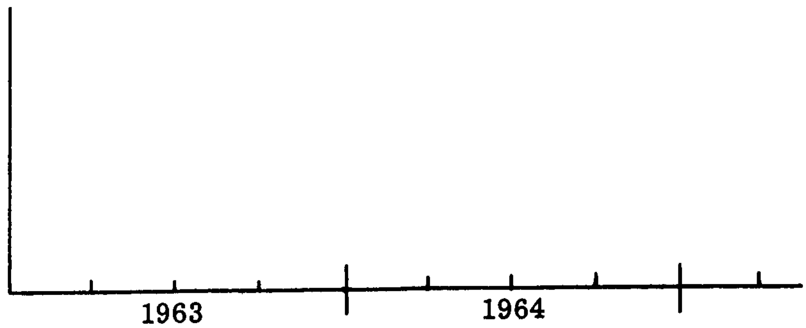


Figure 14-2. S-II Stage

S-II Propulsion System

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Engine Sys.	001						
Prop. Trans. and Press.	011						
Vector Cont.	021						
Eng. Cont. Sys.	031						
Pneu. Cont. Sys.	041						
Ignition	051						
Ordnance	061						
Prop. Util.	071						

Notes:

1.

2.

3.

4.

S-II STAGE PROPULSION (CODE: 03 02 01)

FUNCTION

The propulsion functional system (see Figure 14-3 and 14-4) is the major portion of the S-II stage. Payload capabilities and nominal trajectories are based on nominal J-2 engine parameters.

The engine system will consist of a cluster of five Rocketdyne J-2 liquid propellant rocket engines. Each engine will be a self-contained operational unit automatically performing individual sequence functions following receipt of a minimum number of input signals from the vehicle programmer.

Pitch, yaw, and roll control is provided by gimbaling the four outboard engines through a movement in a 7-degree square pattern with one-half degree additional for overtravel and snubbing. Each control engine is moved by two hydraulic servo-actuators.

The propellant system provides for purging the propellant tanks, loading of liquid oxygen and liquid hydrogen propellants, draining of propellant tanks, suppression of propellant sloshing motion, and prevention of vortex generation. The propellant pressurization system will provide pressurization of ullage space in the propellant tanks to effect flow to the J-2 rocket engines.

Performance parameters of the J-2 engine are shown in Table 14-1.

MAJOR CONTRIBUTORS TO UNRELIABILITY

RELIABILITY TRENDS

CONTRACTORS

Prime -
Engines - Rocketdyne

RELIABILITY DOCUMENTATION

Functional Subsystem: S-II Propulsion (03 02 01)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

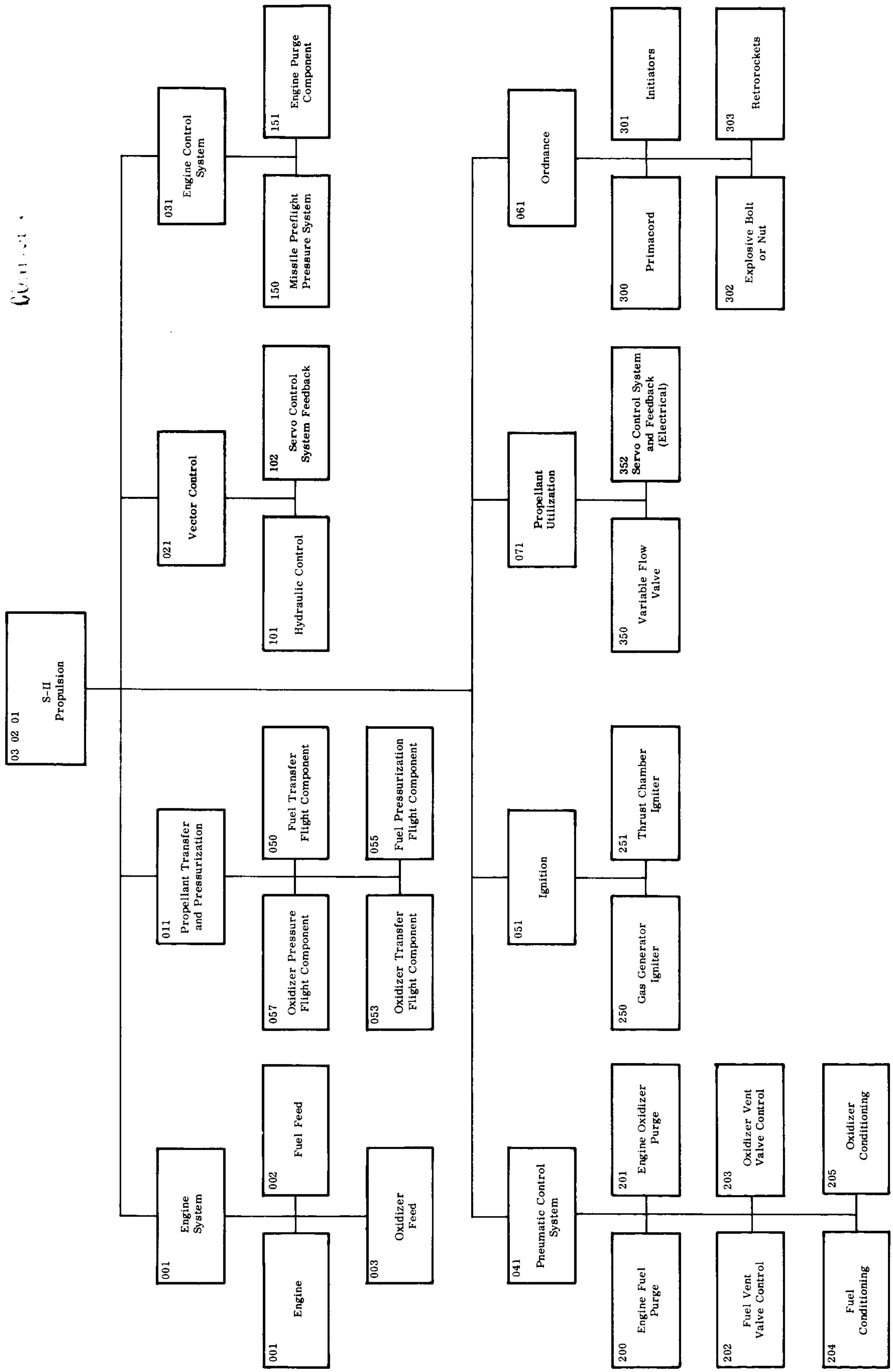


Figure 14-3. S-II Propulsion System Block Diagram

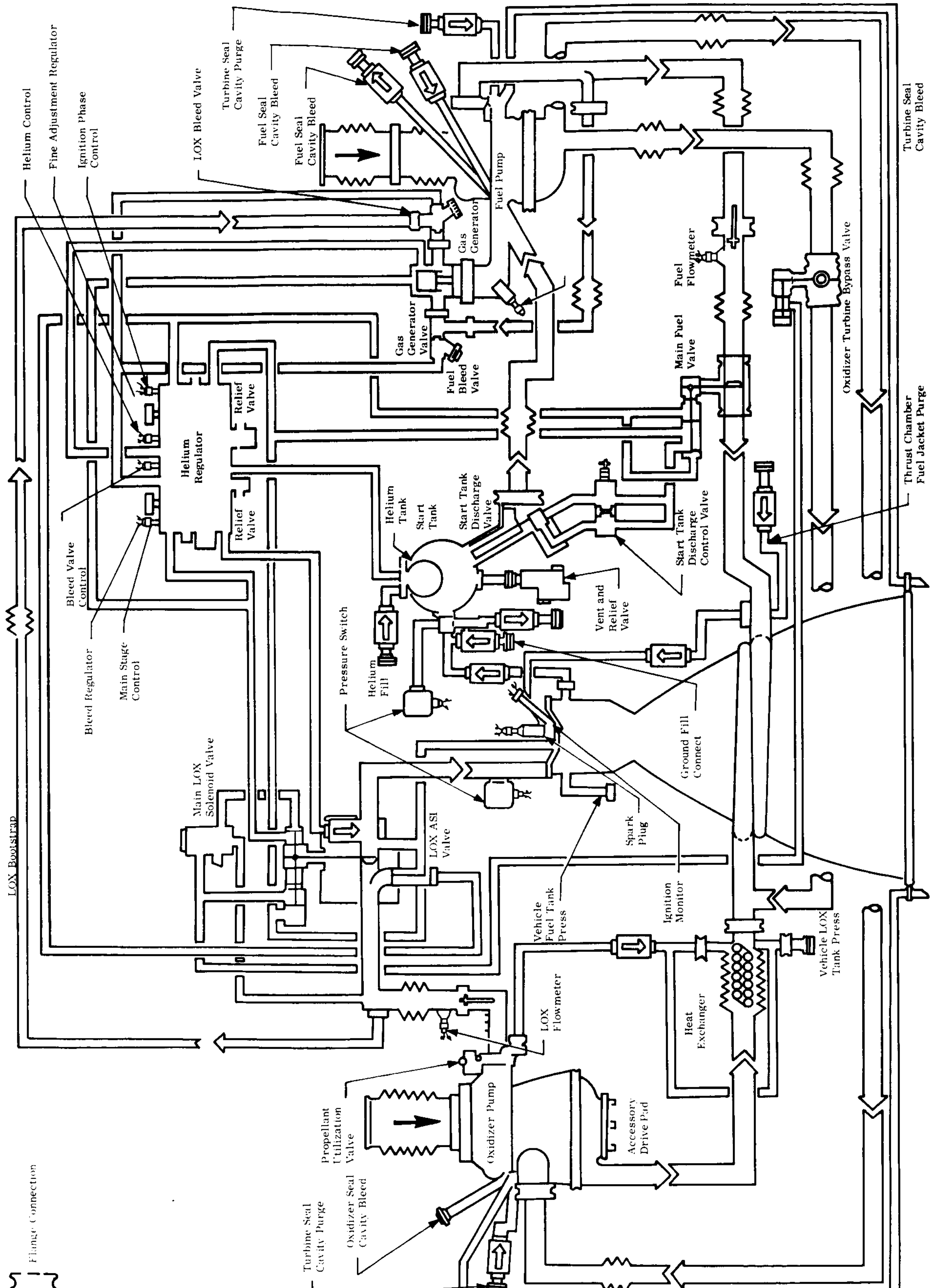


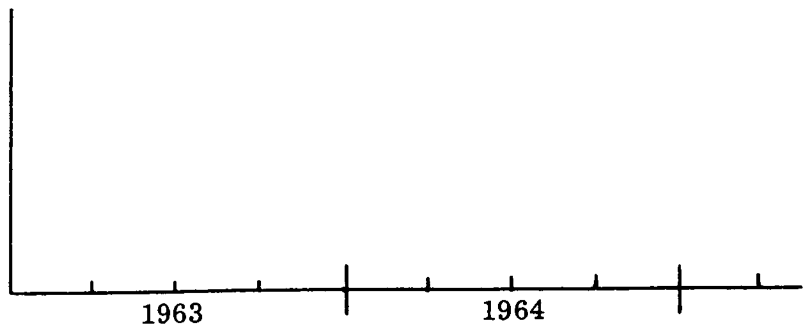
Figure 14-4. J-2 Engine Schematic

Table 14-1
Performance Parameters and Mechanical Characteristics, J-2 Engine

Item	Characteristic
Oxidizer	Liquid oxygen
Fuel	Liquid hydrogen
Thrust (altitude)	200,000 pounds
Specific impluse	426 seconds
Mixture ratio O/F	5.00
Rated Duration	250 seconds
Oxidizer flow rate	291.30 pounds/seconds
Fuel flow rate	78.26 pounds/seconds
Chamber pressure, PSIA	682.5
Expansion ratio	27.5:1
Diameter	80 inches
Length	116 inches
Weight, dry	3028 pounds
Weight, wet	3188 pounds

S-II Electrical Power System

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
DC Power	101						
AC Power	111						
Distribution	121						
Cabling	131						
Interstaging	141						

Notes:

1.
2.
3.
4.

S-II STAGE ELECTRICAL POWER SYSTEM (CODE: 03 02 02)

The launch vehicle power systems are reasonably simple ones in which direct and alternating current needs are supplied by batteries and inverters as appropriate. Certain of the components are items of more or less standard use in the industry. The systems, themselves, however, are not well defined in the information presently available, and their analysis has proceeded on the basis of synthesized systems which are assumed to be most probable configurations. Since relatively subtle changes in the configuration and components used in such a system can have major effect on the reliability achieved, the values thus far derived are of low confidence.

The noise, vibration, and possibly moisture environments are extreme and the line transients resulting from certain equipment operations are of considerable magnitude. These situations affect the reliability of the equipment in use. Accurate evaluation of these factors as applied to the specified Apollo hardware is not presently possible.

RELIABILITY DOCUMENTATION

Functional Subsystem: S-II Electrical Power (03 02 02)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis	N/A	N/A
7. Maintainability Plan - Flight	N/A	N/A
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		

Notes:

1.
2.
3.
4.

S-II STRUCTURES (CODE: 03 02 03)

FUNCTION

MAJOR CONTRIBUTORS TO UNRELIABILITY

RELIABILITY TRENDS

CONTRACTORS

Information adequate for analysis not available 15 September 1963.

S-II Communications

RELIABILITY: Allocated ● Predicted o Achieved x

RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Command	501						
Telemetry	531						
Instrumentation	541						

Notes:

1.
2.
3.
4.

S-II COMMUNICATIONS (CODE: 03 02 06)

FUNCTION

SIC communications (see Figure 14-5) is equipped with measuring, signal conditioning, and telemetry systems for real-time transmission of the operating parameters of the vehicle. An emergency detection system is provided to allow a safe abort of the crew. A command destruct system is also provided in the event of mission abort.

CONTRACTORS

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

NOTE -Information used in analysis based upon synthesized systems.

RELIABILITY DOCUMENTATION

Functional Subsystem: **S-II Communications (03 02 06)**

	Center Submittals Received	
	Yes	**No**
1. **Design Specifications**		X
2. **Top Drawings**		X
3. **Failure Effect Analysis**		X
4. **Criticality Analysis**		X
5. **Performance Analysis**		X
6. **Structural Analysis**		X
7. **Maintainability Plan**		X
8. **Reliability Apportionments**		X
9. **Reliability Model**		X
10. **Quarterly Reliability Reports**		X
11. **Test Results**		X

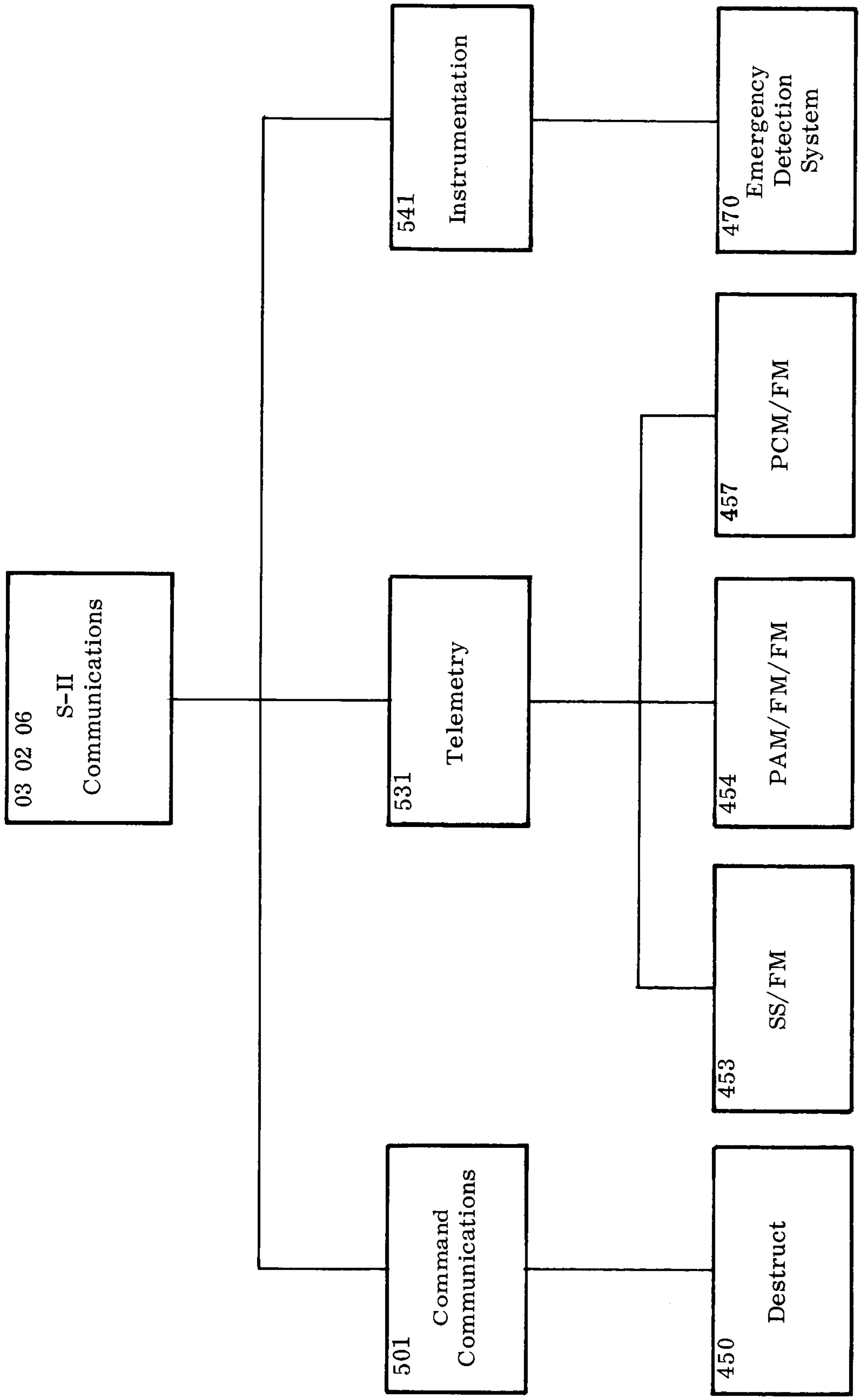


Figure 14-5. S-II Communications Subsystem Block Diagram

SECTION 15

S-IVB STAGE

S-IVB Stage Description

RELIABILITY: Allocated ● Predicted o Achieved x

RELIABILITY

Subsystems	Code	Center Submittal			Percent of Unreliability Contributed	Notes
		Allocated	Predicted	Achieved		
Propulsion	01				7.8	1
Electrical Power	02				0.4	1
Structures	03				-	
Communi-cations	06				-	
React. Control					3.8	1

Notes:

1. Engineering estimate for illustration.
2.
3.
4.

SECTION 15

S-IVB STAGE
(CODE: 03 16)

DESCRIPTION

The over-all S-IVB Stage will be such that it may be applied to early Saturn IB missions or later Saturn V orbital operations, without the necessity of major redesign which may require extensive testing. The S-IVB will be used as the third stage of the advanced Saturn configurations. In the manned lunar landing program this stage is used to provide the escape velocity to the Apollo Spacecraft. The stage configuration is composed of one J-2 engine, a LOX tank and feed system, a hydrogen tank and feed system, and the other associated elements of a boost vehicle.

The engine will be identical to the engines used for the S-II Stage. It will be center mounted and capable of gimbaling a maximum of ±7 degrees in a square pattern, with an additional 1/2-degree allowable for overtravel, snubbing, misalignment, etc.

A 3000-psi cold gas helium system is provided for liquid oxygen tank pressurization, and the hydrogen tank will be pressurized in flight by bleed hydrogen from the engine and prepressurized with cold helium from a ground source.

A closed-loop propellant utilization system will be designed with the capability of limiting total residual propellants over and above unusable propellants to 1000 pounds.

CONTRACTORS

Prime - Douglas Aircraft Company

Engine - Rocketdyne

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

RELIABILITY DOCUMENTATION

Subsystems: S-IVB

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis	1	
4. Criticality Analysis	1	
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Notes:

1. Some of the available data pertains to the S-IV stage since little information has as yet been provided regarding the S-IVB stage.
2.
3.
4.

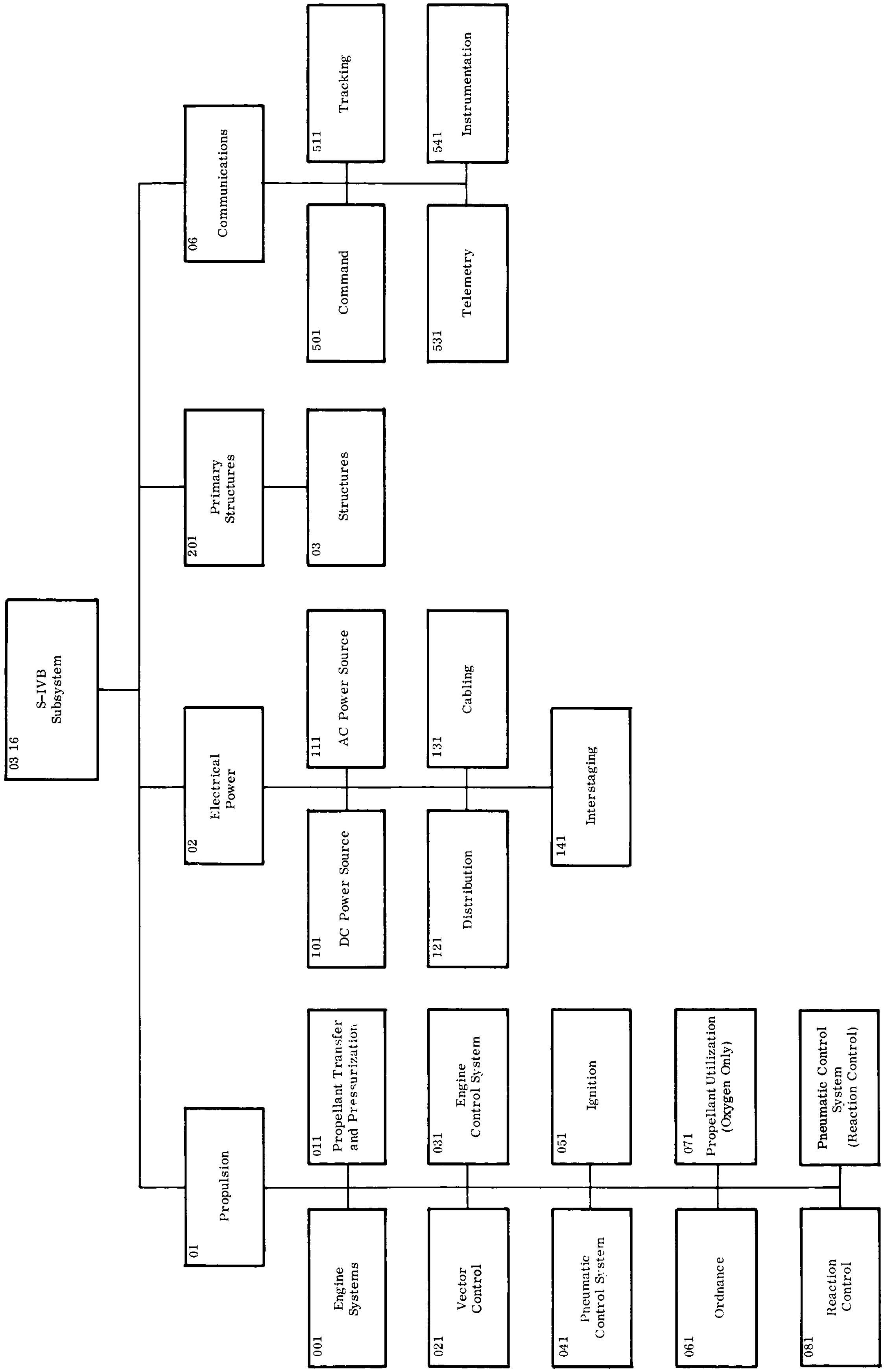


Figure 15-1. S-IVB Stage Block Diagram

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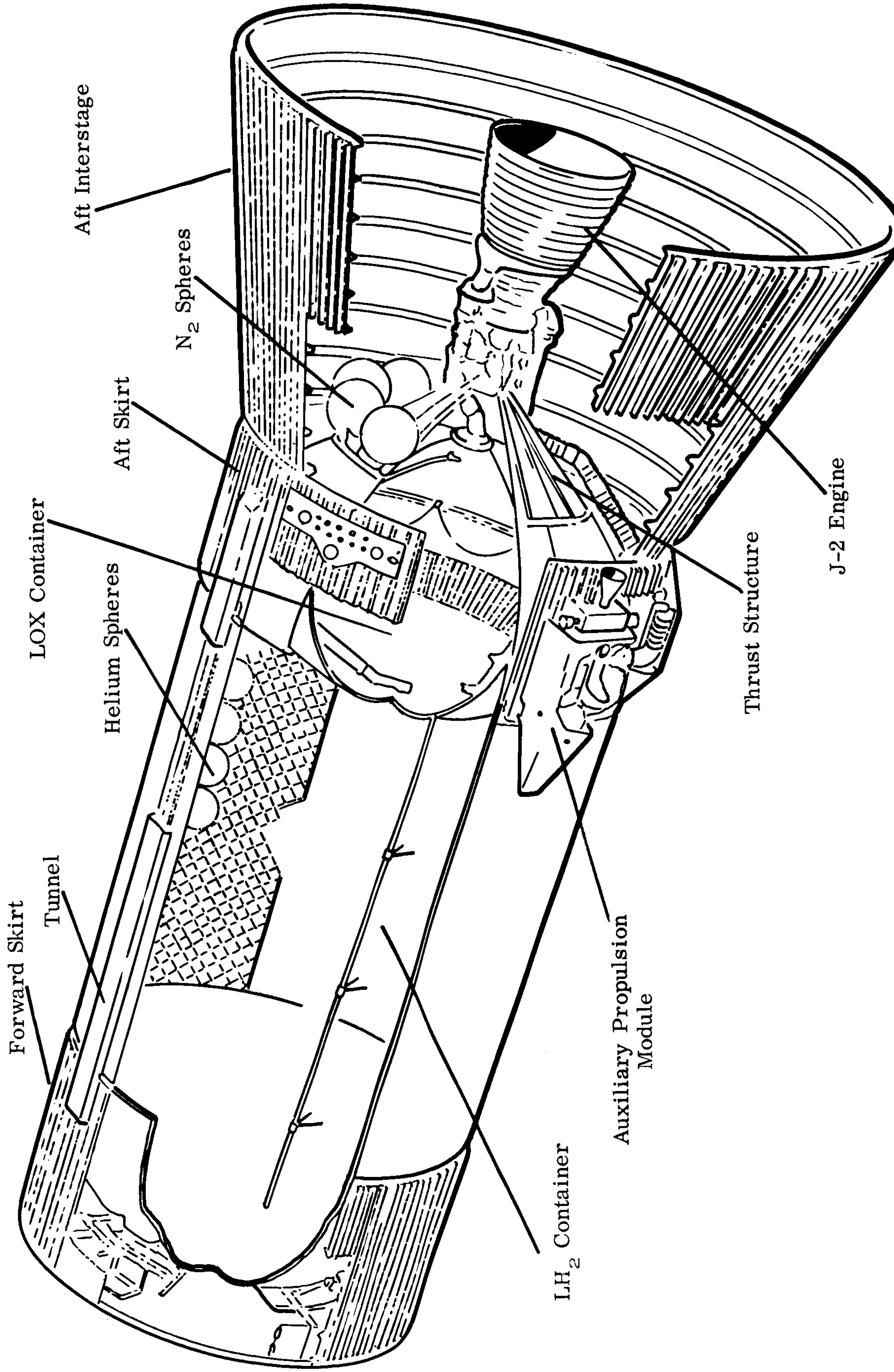
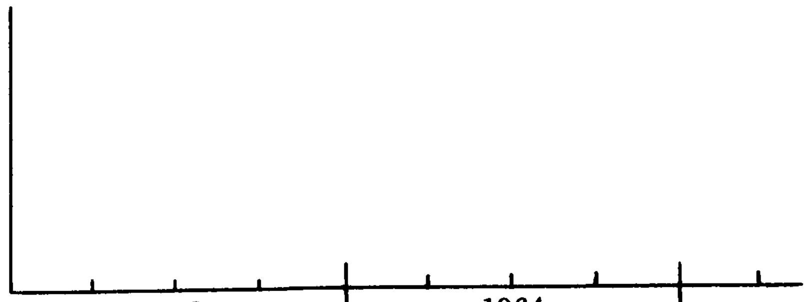


Figure 15-2. S-IVB Stage Profile

S-IVB Propulsion System

RELIABILITY: Allocated • Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Engine Systems	001						
Propellant Transfer and Utilization	011						
Vector Control	021						
Engine Control	031						
Pneumatic Control	041						
Propellant Utilization (oxidizer only)	071						
Ordnance	061						
Ignition	051						
Reaction Control	081						

Notes:

1.
2.
3.
4.

S-IVB PROPULSION SYSTEM (CODE: 03 16 01)

FUNCTION

The propulsion system consists of one J-2 engine with a thrust of 200, 000 pounds vacuum rating and a hypergolic powered roll and attitude control system. The engine will be capable of gimbaling a maximum of ±7 degrees in a square pattern, with an additional 1/2-degree allowable for overtravel, snubbing, misalignment, etc.

A propellant pressurization system is provided with a 3000-psi cold gas helium system to pressurize the liquid oxygen tank and a hydrogen bleed from the engine coupled with pressurized helium to pressurize the hydrogen tank.

A closed-loop propellant utilization system will be designed with the capability of limiting total residualpropellants over and above unusable propellants to 1000 pounds. In addition, the system will be designed to provide an input to the propellant loading system to control the mass of propellant loading.

Ground purging or conditioning of the S-II/S-IVB interstage compartment will be accomplished with gaseous nitrogen.

Retrorockets will be solid propellant rocket motors.

A closed-loop hydraulic system will be used to provide control power for engine gimbaling.

CONTRACTORS

Prime Contractors

- Propulsion Engine - Rocketdyne
- Retrorockets - Thiokol

MAJOR CONTRIBUTORS TO UNRELIABILITY

RELIABILITY TRENDS

RELIABILITY DOCUMENTATION

Functional Subsystem: S-IVB Propulsion

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

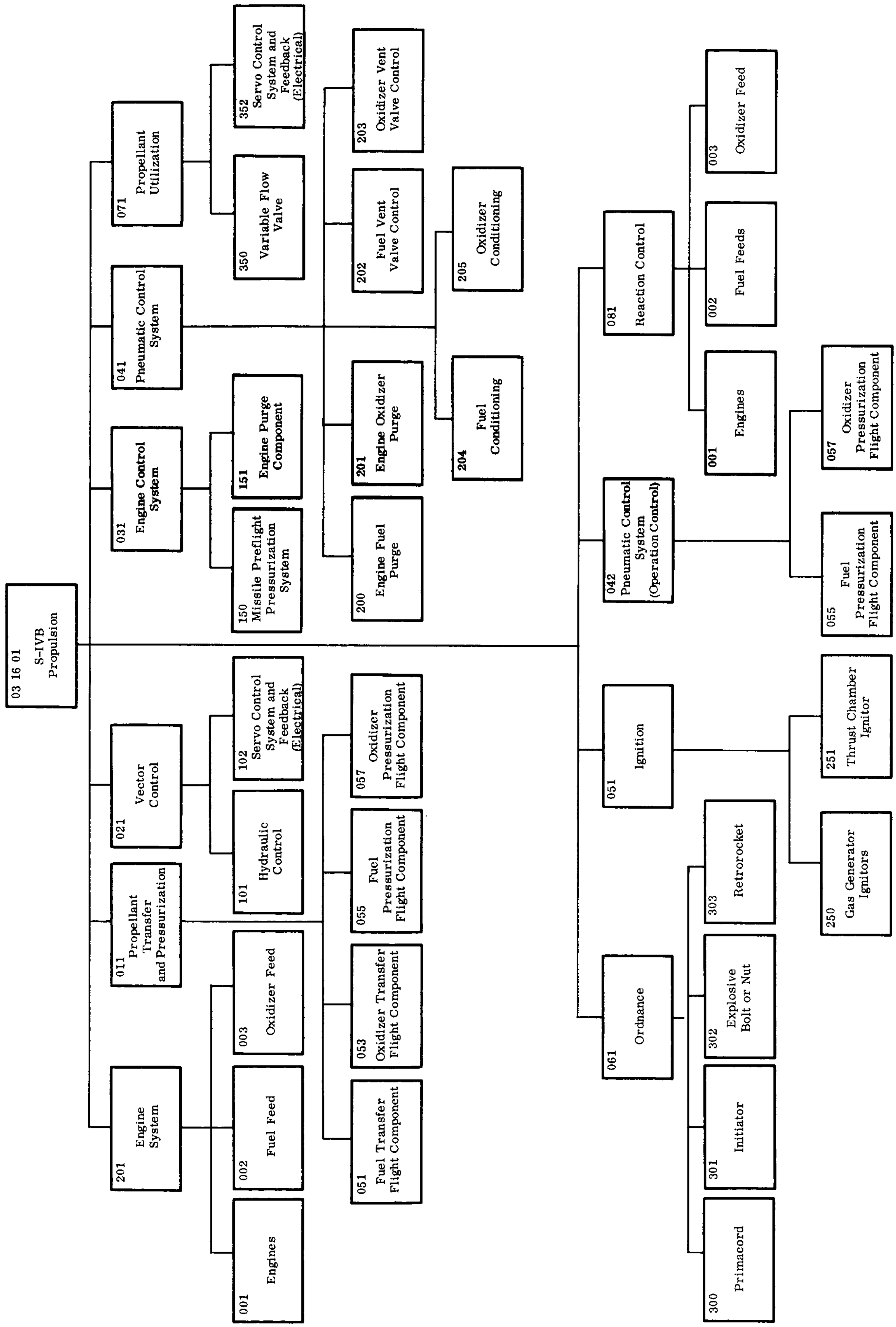


Figure 15-3. S-IVB Propulsion Block Diagram

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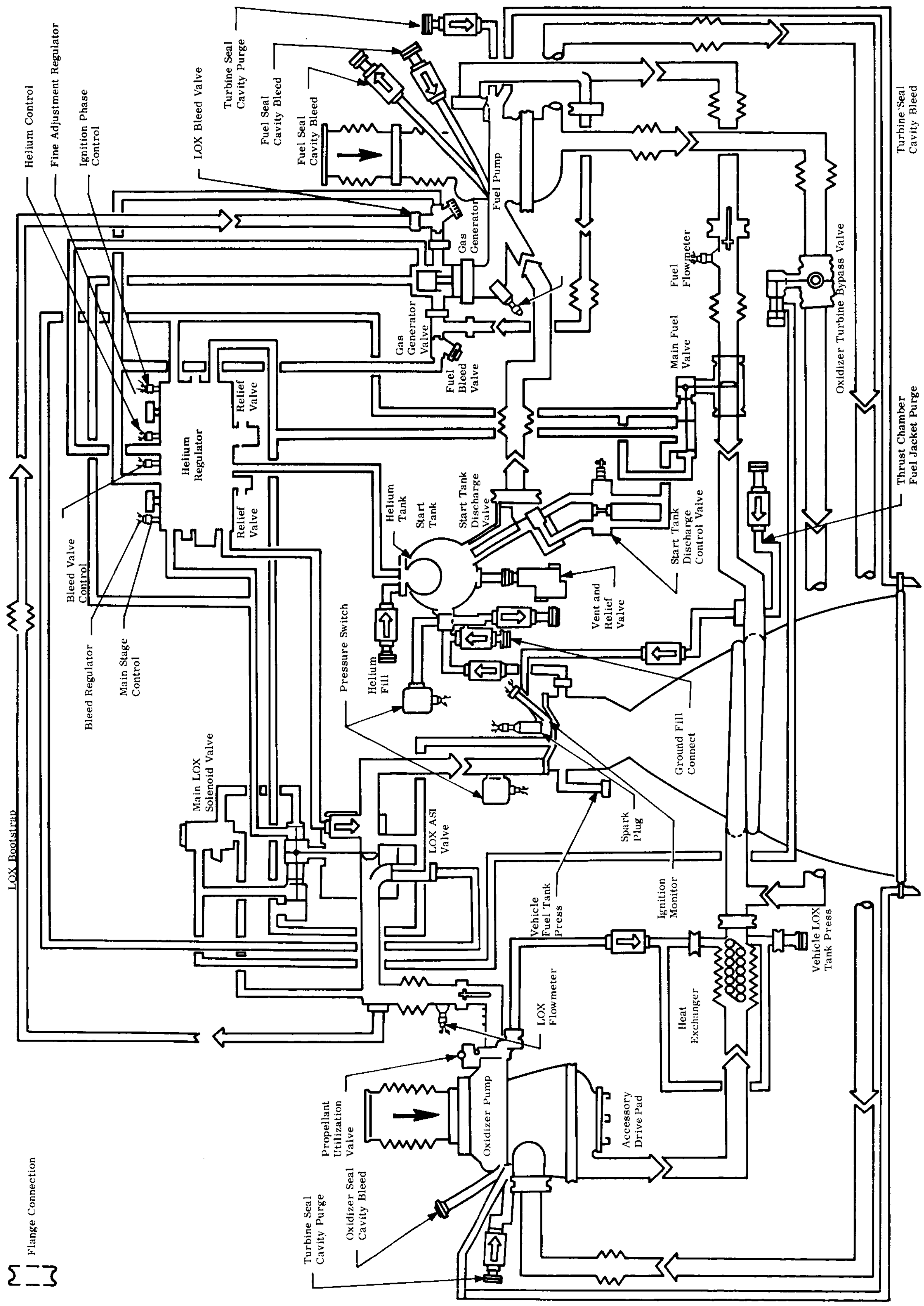
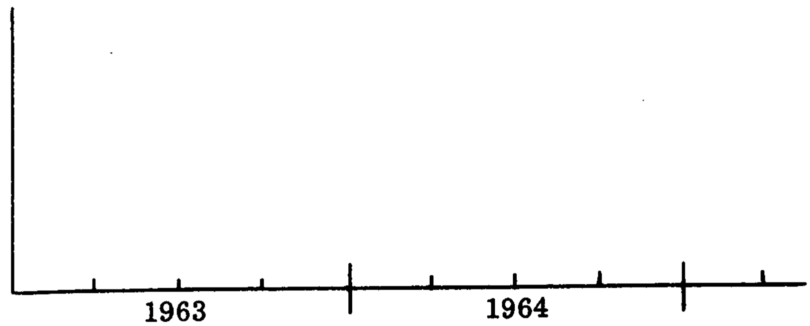


Figure 15-4. J-2 Engine

S-IVB Electrical Power System

RELIABILITY: Allocated $\underline{\bullet}$ Predicted $\underline{o}$ Achieved $\underline{x}$



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
DC Power	101						
AC Power	111						
Distribution	121						
Cabling	131						
Interstaging	141						

Notes:

1.
2.
3.
4.

S-IVB STAGE ELECTRICAL POWER SYSTEMS

The power systems are reasonably simple ones in which direct and alternating current needs are supplied by batteries and inverters as appropriate. Certain of the components are items of more or less standard use in the industry. The systems, themselves, however, are not well defined in the information presently available, and their analysis has proceeded on the basis of synthesized systems which are assumed to be most probable configurations. Since relatively subtle changes in the configuration and components used in such a system can have major effect on the reliability achieved, the values thus far derived are of low confidence.

The launch vehicle operations are of relatively short duration. The noise, vibration, and possibly moisture environment are extreme and the line transients resulting from certain equipment operations are of considerable magnitude. These situations have an effect upon the reliability of the equipment in use. Accurate evaluation of these factors as applied to the specified Apollo hardware is not presently possible.

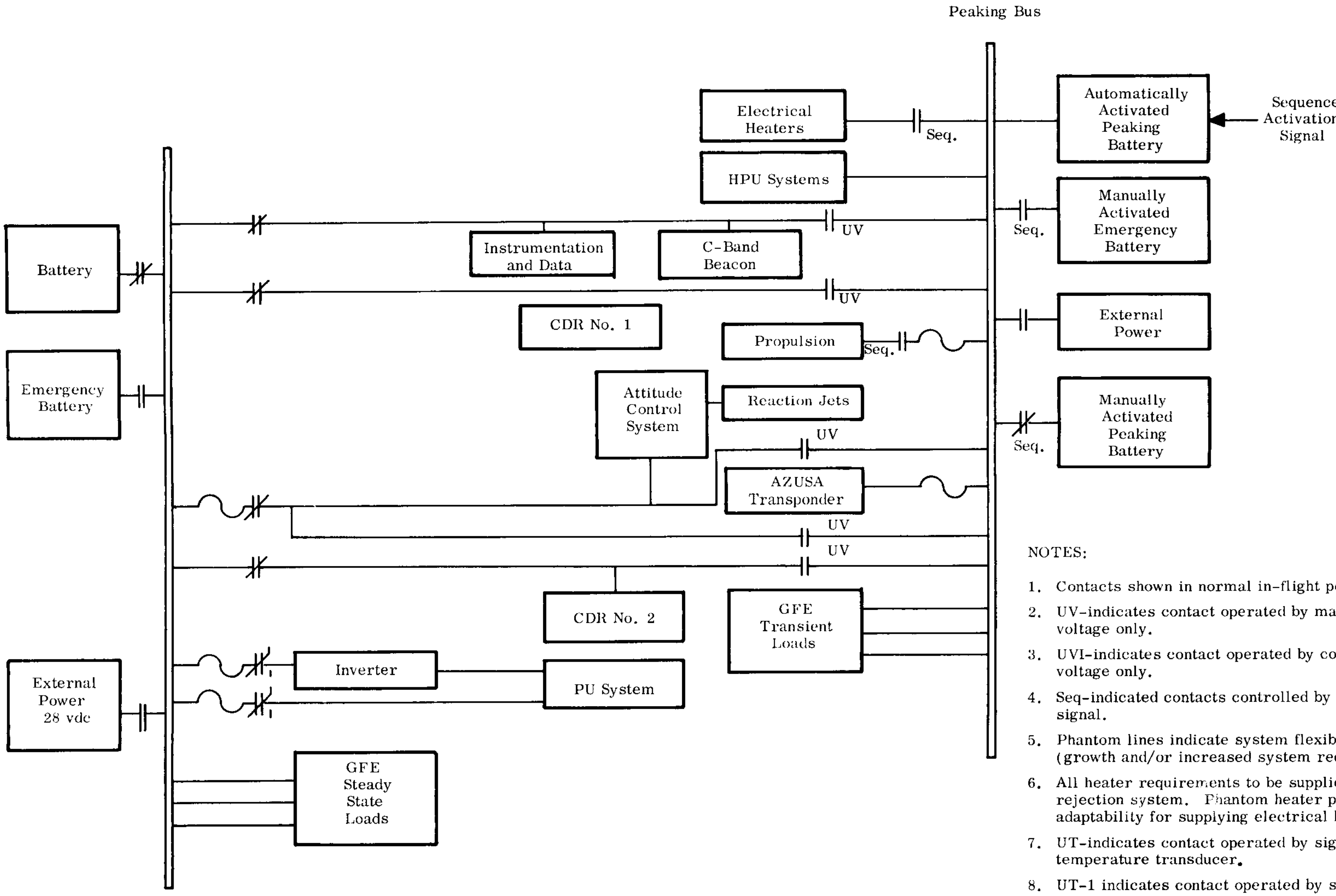
RELIABILITY DOCUMENTATION

Functional Subsystem: S-IVB Electrical Power (03 16 02)

	Center Submittals Received	
	Yes	No
1. Design Specifications		1
2. Top Drawings		1
3. Failure Effect Analysis		1
4. Criticality Analysis		1
5. Performance Analysis		1
6. Structural Analysis		1
7. Maintainability Plan		1
8. Reliability Apportionments		1
9. Reliability Model		1
10. Quarterly Reliability Reports		1
11. Test Results		1

Notes:

1. Information not available as of 15 September 1963.
2.
3.
4.



NOTES:

1. Contacts shown in normal in-flight position.
2. UV-indicates contact operated by main bus under voltage only.
3. UVI-indicates contact operated by converter under voltage only.
4. Seq-indicated contacts controlled by vehicle sequencer signal.
5. Phantom lines indicate system flexibility for load (growth and/or increased system redundancy).
6. All heater requirements to be supplied by the heater rejection system. Phantom heater power module shows adaptability for supplying electrical heaters if required.
7. UT-indicates contact operated by signal from high temperature transducer.
8. UT-1 indicates contact operated by signal from low temperature transducer for motor starting.
9. The emergency battery to supply backup power for diagnostic telemetry and command destruct units.

Figure 15-5. Power System Block Diagram

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S-IVB STRUCTURES (CODE: 03 16 03)

FUNCTION

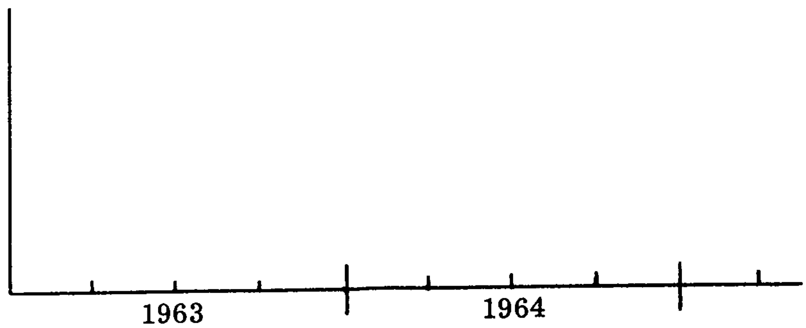
MAJOR CONTRIBUTORS TO UNRELIABILITY

RELIABILITY TRENDS

CONTRACTORS

S-IVB Communications

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Command Communications	501						
Tracing	511						
Telemetry	531						
Instrumentation	541						

Notes:

1.
2.
3.
4.

S-IVB COMMUNICATIONS (CODE: 03 16 06)

FUNCTION

S-IVB communications is equipped with measuring, signal conditioning, and telemetry systems for real time transmission of the operating parameters of the vehicle. An emergency detection system is provided to allow a safe abort of the crew. A command destruct system is also provided in the event of mission abort.

CONTRACTORS

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

RELIABILITY DOCUMENTATION

Functional Subsystem: S-IVB Communications (03 16 06)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		Not applicable
7. Maintainability Plan - Flight	Not applicable	Not applicable
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

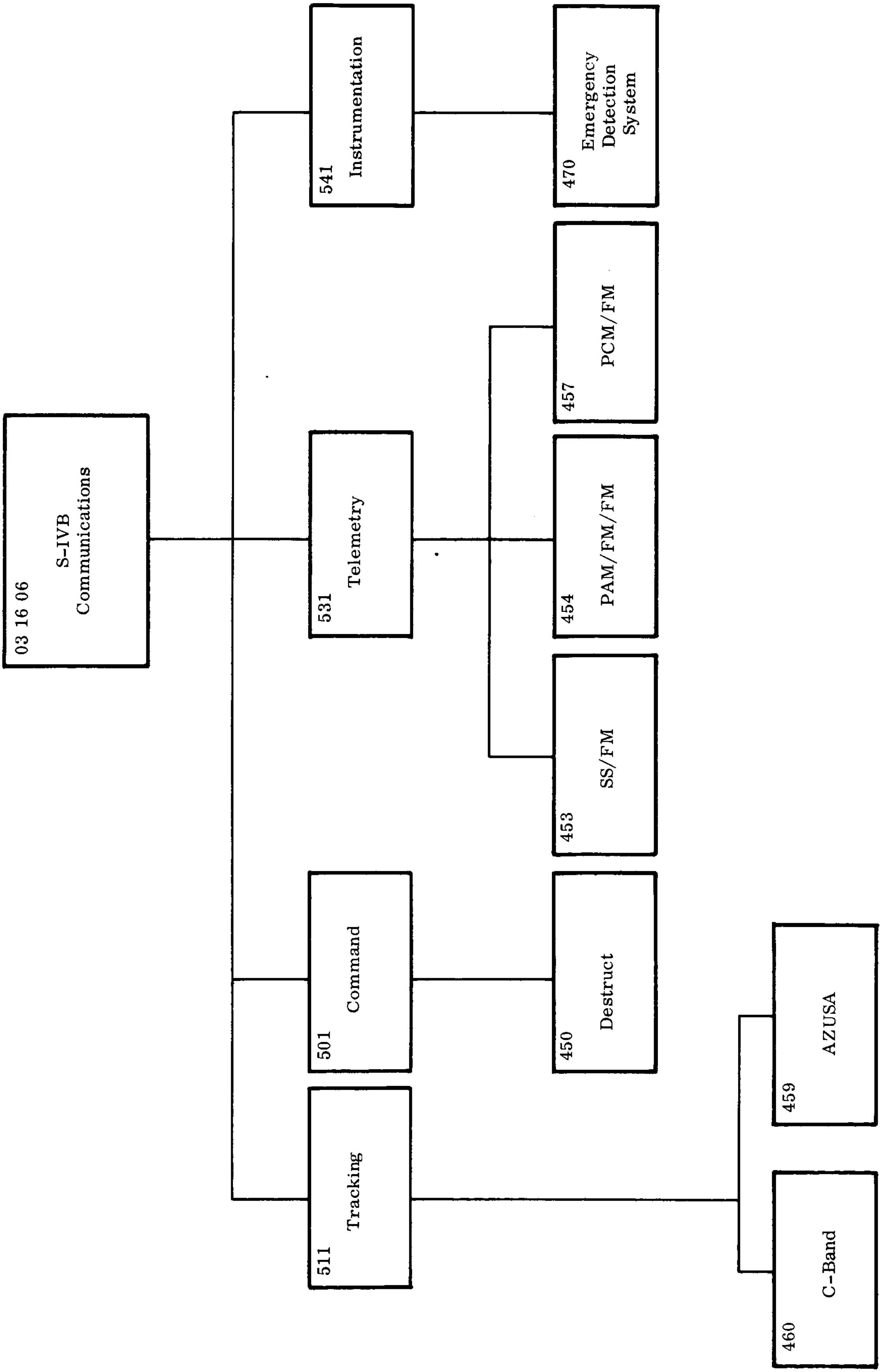


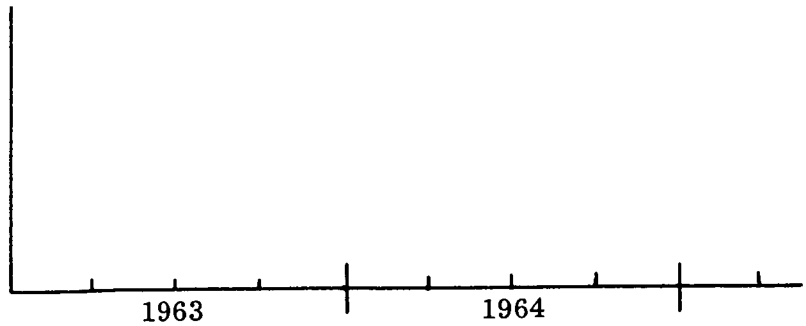
Figure 15-6. S-IVB Communications

SECTION 16

INSTRUMENT UNIT

Instrument Unit Description

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Percent of Unreliability Contributed	Notes
		Allocated	Predicted	Achieved		
Electrical power	02				0	1
Structure	03				-	
Environmental Control	04				1.2	1
Guidance	05				6.8	1
Communications	06				-	

Notes:

1. Engineering estimate for illustration.
2.
3.
4.

SECTION 16

INSTRUMENT UNIT (CODE: 03 05)

INSTRUMENT UNIT DESCRIPTION (CODE: 03 05)

FUNCTION

The instrument unit is an interstage adapter between the launch vehicle and the spacecraft. It houses the launch guidance and control system, an emergency detection system, and various RF components including tracking transponders, telemetry transmitters, and command receivers. The structure is permanently attached to the S-IVB stage, and includes a separation interface at the spacecraft.

CONTRACTORS

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

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RELIABILITY DOCUMENTATION

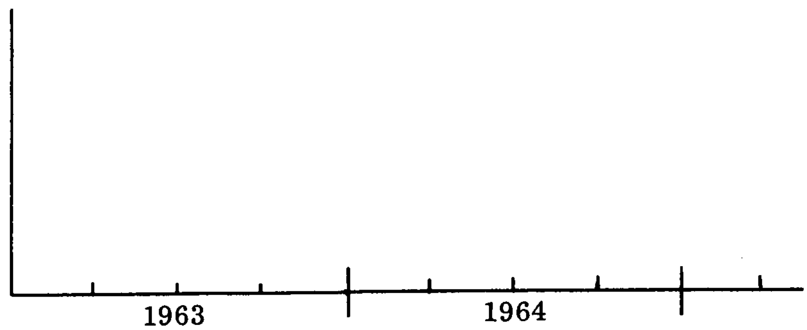
Functional Subsystem: Instrument Unit (Code: 03 05)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Notes:

1. Data not available as of 15 September 1963.
2.
3.
4.

Instrument Unit Electrical
Power System
RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
DC Power source	101						
AC Power source	111						
Distribution	121						
Cabling	131						
Interstaging	141						

Notes:

1.
2.
3.
4.

INSTRUMENT UNIT ELECTRICAL POWER SYSTEM

The power systems are reasonably simple ones in which direct and alternating current needs are supplied by batteries and inverters as appropriate. Certain of the components are items of more or less standard use in the industry. The systems, themselves, however, are not well defined in the information presently available, and their analysis has proceeded on the basis of synthesized systems which are assumed to be most probable configurations. Since relatively subtle changes in the configuration and components used in such a system can have a major effect on the reliability achieved, the values thus far derived are of low confidence.

The launch vehicle operations are of relatively short duration. The noise, vibration, and possibly moisture environment are extreme and the line transients resulting from certain equipment operations are of considerable magnitude. These situations have an effect upon the reliability of the equipment in use. Accurate evaluation of these factors as applied to the specified Apollo hardware is not presently possible.

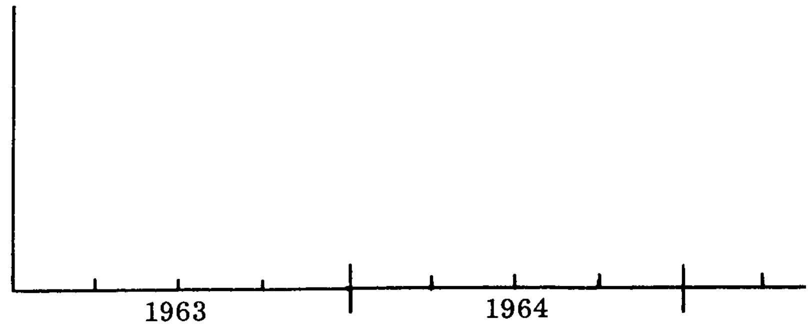
RELIABILITY DOCUMENTATION

Functional Subsystem: Instrument Unit Electrical Power (Code: 03 05 02)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

INSTRUMENT UNIT STRUCTURES (CODE: 03 05 03)

Instrument Unit Environmental
Control System
RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Pressurization Regulator	312						
Liquid Nitrogen Cooling	313						
Circulation System	314						

Notes:

1.
2.
3.
4.

INSTRUMENT UNIT ENVIRONMENTAL CONTROL SYSTEM (CODE: 03 05 04) DESCRIPTION

FUNCTION

The function of the environmental control system in the instrument unit is primarily the maintenance of suitable operating temperature for the electronic equipment aboard. The unit is a gaseous nitrogen system, but its elements are not presently well defined. Earlier Saturn vehicle instrumentation carried equipment which has been assumed to be similar to that intended for the Apollo launch vehicles and preliminary estimates made on this basis. Since many of the critical components of the launch vehicle guidance are dependent upon this system, it has direct effect upon the mission reliability and safety. Further definition will be required for the development of accurate predictions.

CONTRACTORS

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

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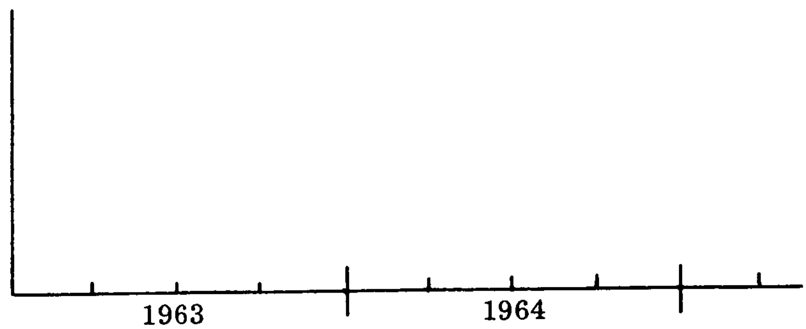
RELIABILITY DOCUMENTATION

Functional Subsystem: Instrument Unit Environmental Control (Code: 03 05 04)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

[redacted]

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
ST-124	503				0.96729		2
Digital Guid. Comp.	504				0.99898		1, 2
Guid. Sig. Proc.	505				0.98528		2
Azi. Align. Package	506						
Control Computer	507				0.99953		2
Decoder	508						
GN_2 Bearing Supply	509						
Flt. Seq.	510						

Notes:

1. Reliability figure was based on ASC-15 computer assuming it to be similar for failure predictions.
2. Reliability predictions based on preliminary study of Saturn V vehicle report by ARINC dated 30 June 1963.
3.
4.

[redacted]
DRAFT

INSTRUMENT UNIT GUIDANCE AND CONTROL SYSTEM (CODE: 03 05 05 411)

FUNCTION

The adaptive guidance mode concept is used to meet the severe requirements placed on the guidance system. This mode functions by accepting the present vehicle flight variables and engine parameter as initial conditions and defining the optimum path ahead which meets the mission requirements.

The major subsystems are a four gimbal inertial platform, general purpose digital computer, and an analog computer. (See Figure 16-1.)

CONTRACTORS

MAJOR CONTRIBUTORS TO UNRELIABILITY

RELIABILITY TRENDS

RELIABILITY DOCUMENTATION

Functional Subsystem: Instrument Unit Guidance and Control System

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings	April 1962	
3. Failure Effect Analysis		X
4. Criticality Analysis		
5. Performance Analysis		X
6. Structural Analysis	Not Applicable	Not Applicable
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

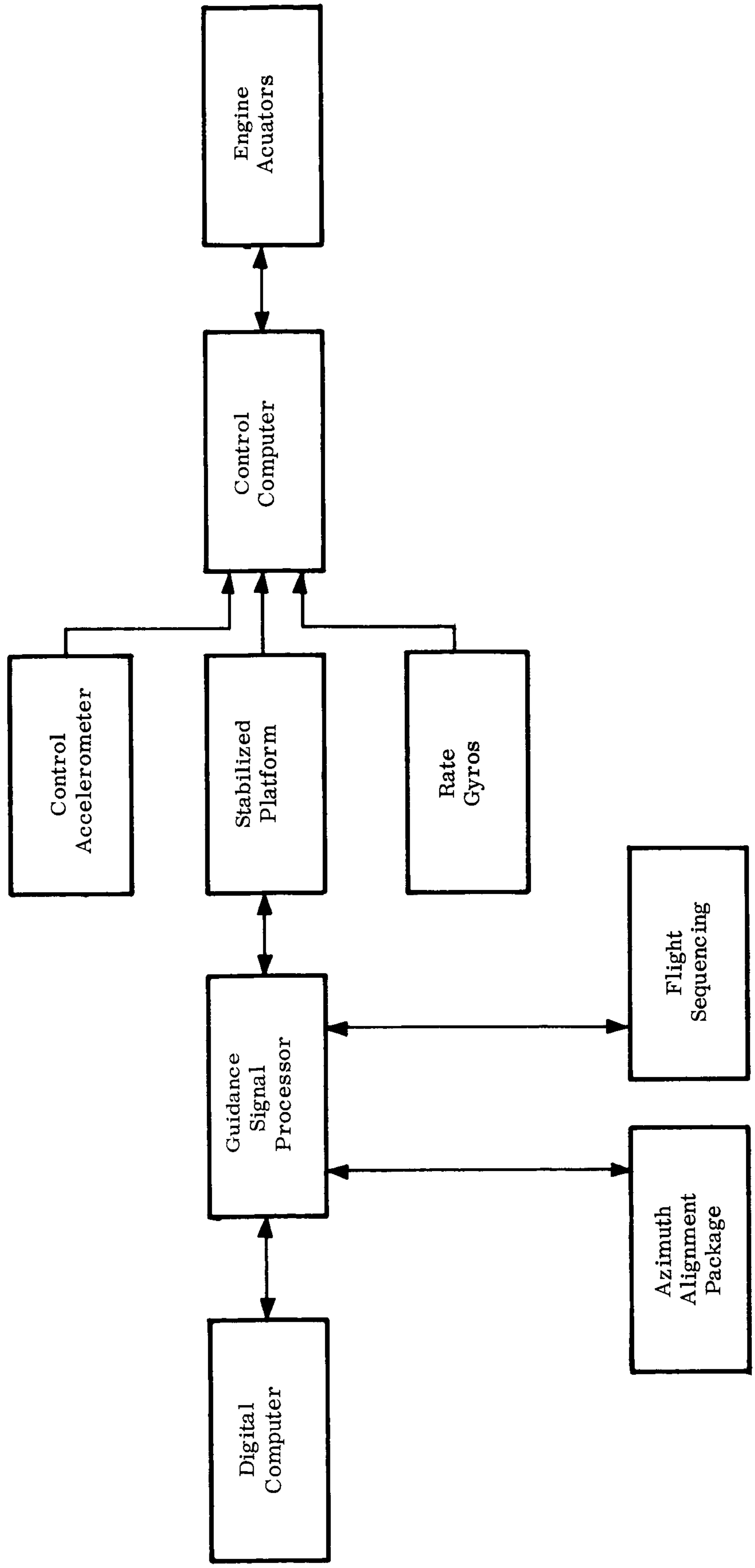
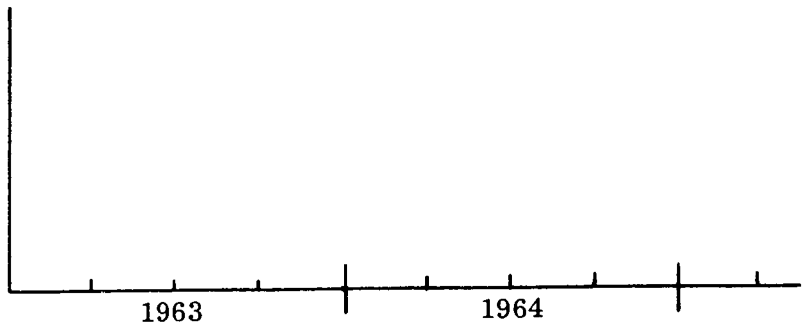


Figure 16-1. Guidance and Control System

Instrument Unit Communications

RELIABILITY: Allocated • Predicted o Achieved x



RELIABILITY

		Center Submittal			Industry		
Subsystems	Code	Allocated	Predicted	Achieved	Best	Average	Notes
Telemetry	531						
Tracking	511						

Notes:

1.
2.
3.
4.

INSTRUMENT UNIT COMMUNICATIONS (CODE: 03 05 06)

FUNCTION

Instrument unit communications is equipped with measuring, signal conditioning, and telemetry system for realtime transmission of the operating parameters of the vehicles. Tracking subsystems are provided to determine launch trajectory and near earth orbit. (See Figure 16-2.)

CONTRACTORS

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

RELIABILITY DOCUMENTATION

Functional Subsystem: Instrument Unit Communications (Code: 03 05 06)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings	April 1962	
3. Failure Effect Analysis		X
4. Criticality Analysis		
5. Performance Analysis		X
6. Structural Analysis	Not Applicable	Not Applicable
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

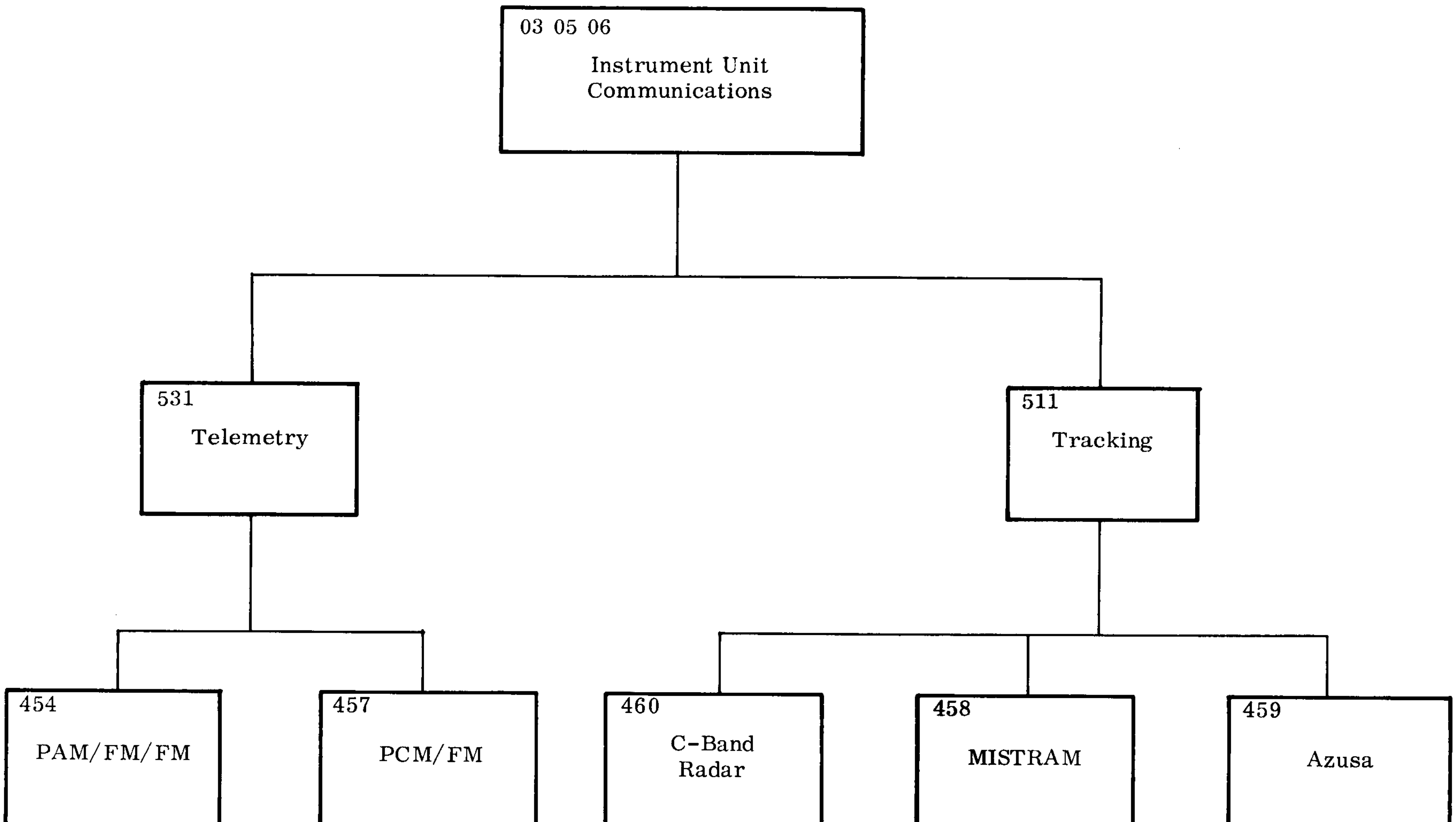


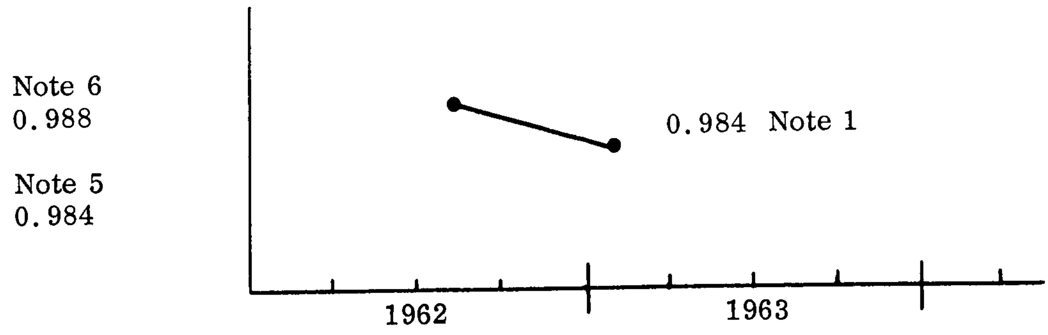
Figure 16-2. Instrument Unit Communications Functional Block Diagram

SECTION 17

LUNAR EXCURSION MODULE

Lunar Excursion Module Description

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Percent of Unreliability Contributed	Notes
		Allocated	Predicted	Achieved		
Propulsion	01	0.999968	0.99972		10.8	4
Electrical Power (CM/SM)	02	0.998953	0.9941		7.5	1,4
Structures	03		0.999994		----	1
Environmental Control	04	0.999154			2.8	2
Guidance	05	0.992183			6.1	3
Stabilization and Control		0.992285				
Communications	06				----	
Crew System	07				----	
Reaction Control					1.2	

Notes:

1. NAA 62-557-4
2. Allocation: Grumman Aiv. Gen. Co. Data
3. Allocation: GAEC LPR 550-1
4. Allocation: NAA 62-557-5
5. NASw: 410 61 14 01
6. NASw: 410 60 14 01

SECTION 17

LUNAR EXCURSION MODULE
(CODE: 03 06)

DESCRIPTION

The lunar excursion module will serve as a vehicle for carrying two of the crew members and payload from the spacecraft in a lunar orbit to the lunar surface and back. This module will have the capability of performing the separation, lunar descent, hovering and translation, landing, ascent, rendezvous, and docking independent of the spacecraft. The lunar excursion module will allow for crew exploration in the vicinity of the lunar touchdown; it is not required to have lunar surface mobility. The lunar excursion module will contain the communication, navigation, guidance, control, computing, display equipment, etc. Equipment arrangements will allow access for maintenance, both before and after earth launch. The module will not be recoverable.

CONTRACTORS

Prime Contractor - MSC/Grumman Aircraft Engineering Company

- Communications - RCA
- Electrical Power - Pratt & Whitney
- Reaction Control - Marquardt

Propulsion -

Environmental Control - Hamilton Standard

Guidance - MIT: ACSP/Raytheon/Kollsman: RCA

Structure - Grumman

MAJOR CONTRIBUTOR TO UNRELIABILITY

Recent reviews of the planned reliability programs supporting the spacecraft and LEM hardware development have shown fundamental differences in the philosophies guiding the reliability programs. Resolution of the differences to allow meaningful comparisons of values attained will be necessary and is underway. Specifically, the North American testing philosophy is based upon mission simulations in which attributes data are recorded. On the other hand, Grumman uses a qualification test-to-failure technique which provides data of a different sort.

RELIABILITY TRENDS

Estimates made largely by the basis of study and proposal material.

RELIABILITY DOCUMENTATION

Functional Subsystem: LEM (03 06)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments	1	
9. Reliability Model	1	
10. Quarterly Reliability Reports	1	
11. Test Results		X

Notes:

1. Partial information, GAEC LPR 550-1.
2.
3.
4.

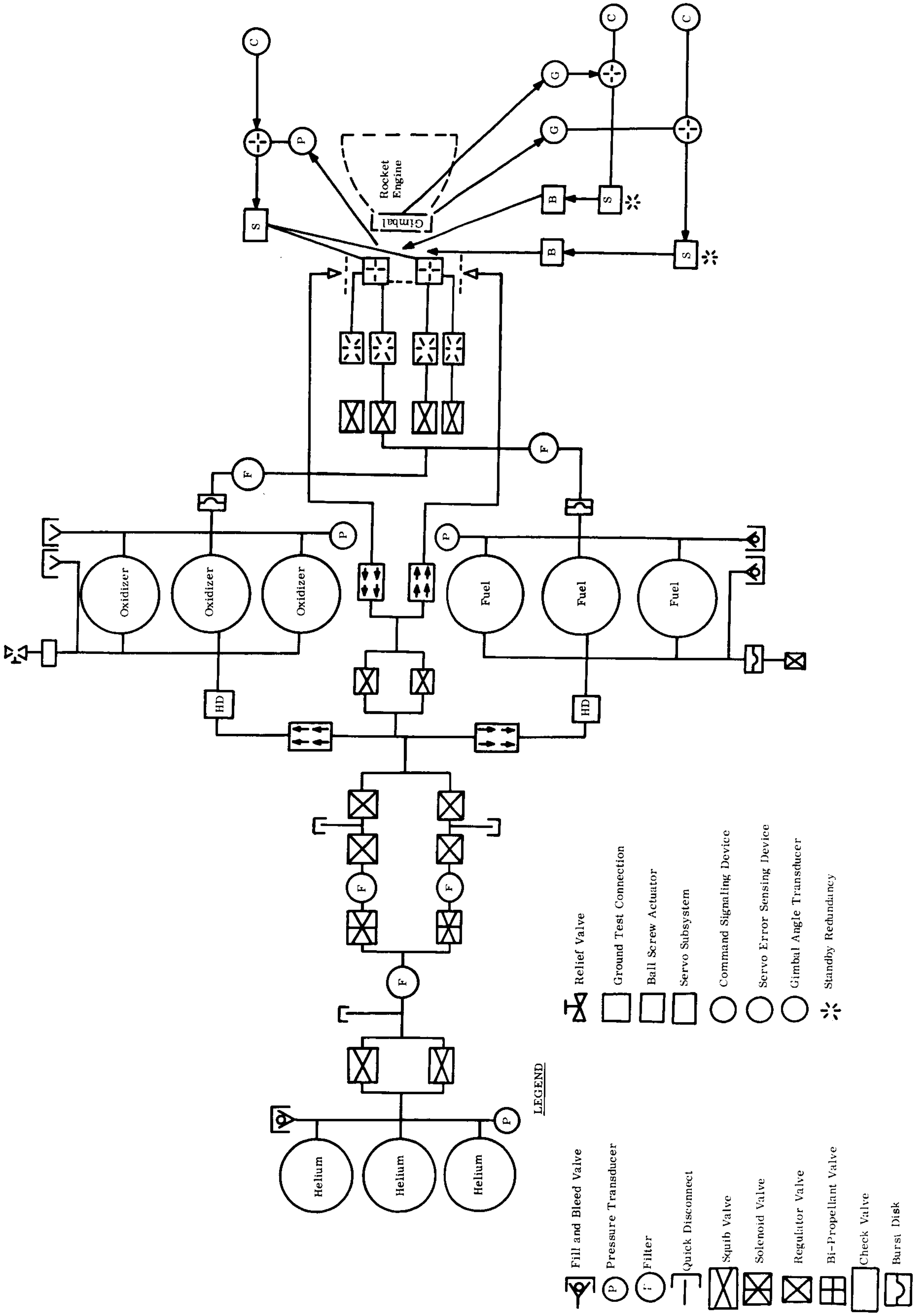


Figure 17-1. Functional Block Diagram Descent Schematic

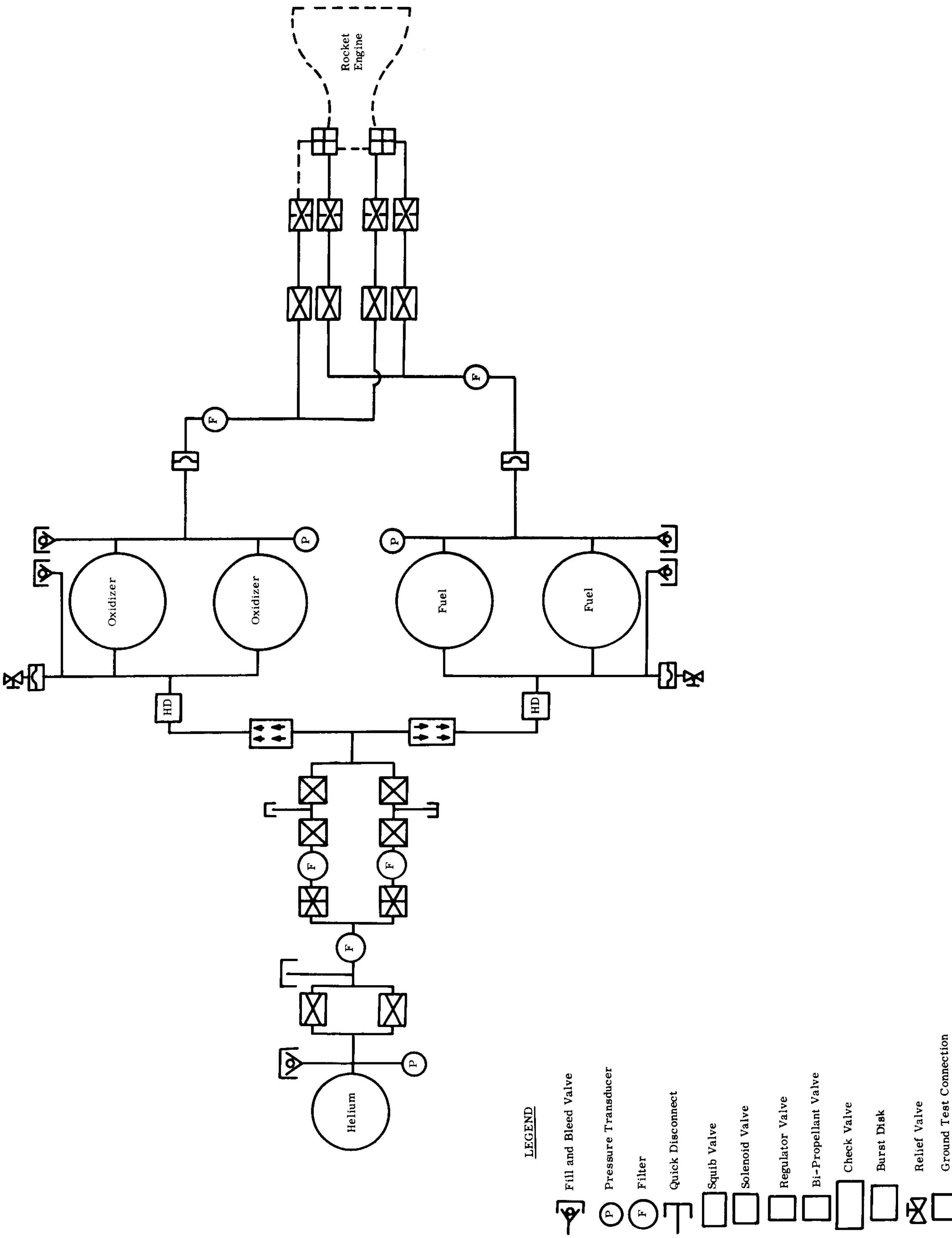


Figure 17-2. Functional Diagram Ascent Schematic

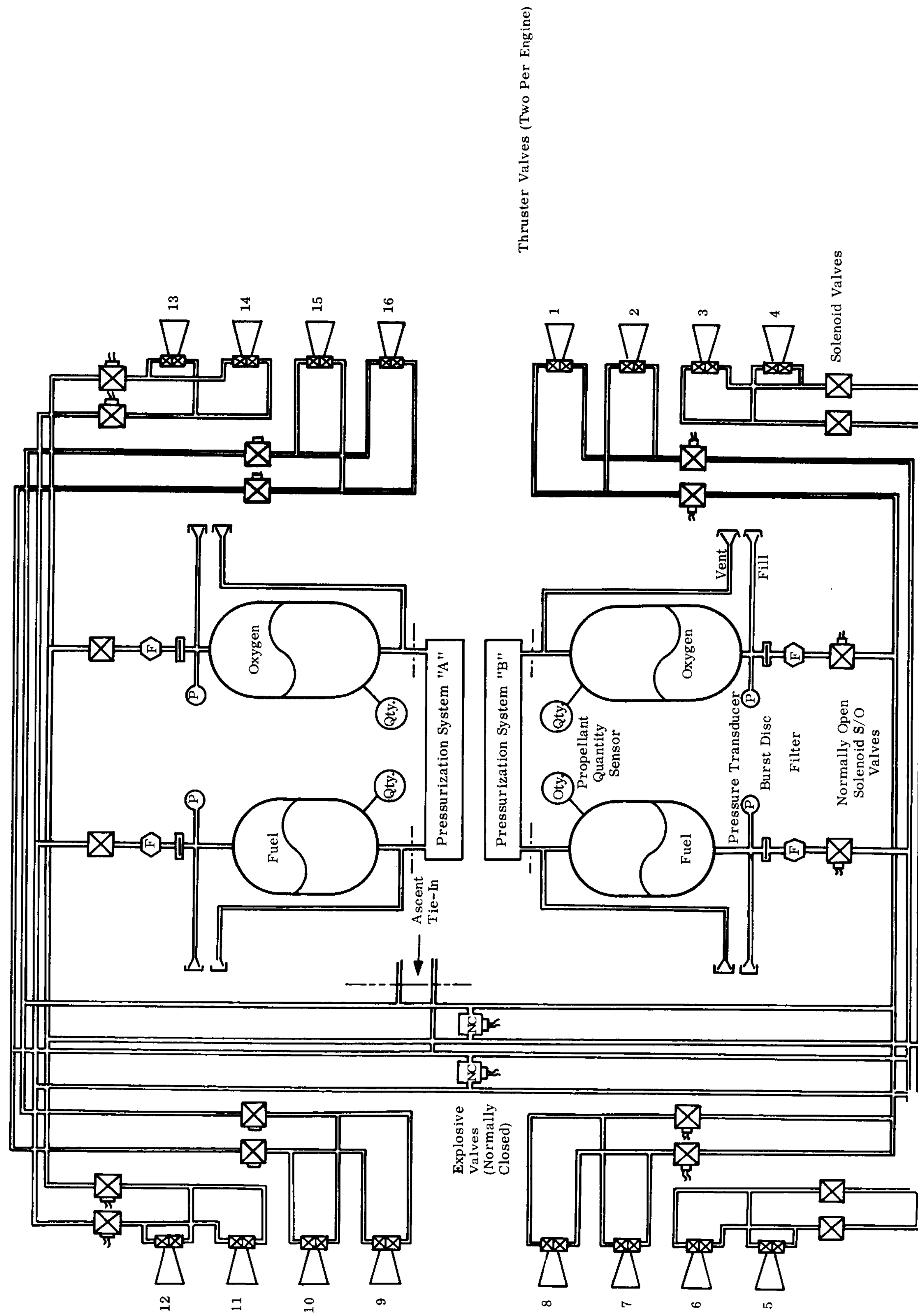
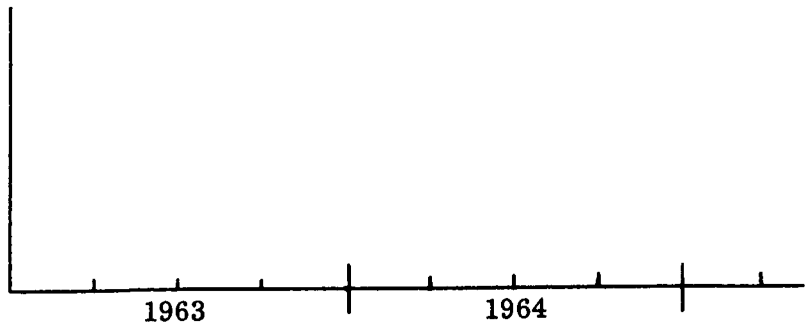


Figure 17-3. Propellant and Thrust Chamber Section Schematic

Lunar Excursion Module Propulsion System

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Engine System	001						
Propellant Transfer and Pressurization	011						
Vector Control	021						
Pneumatic Control	041						
Ignition	051						
Propellant Utilization	071						
Reaction Control	081						
Ordnance	061						

Notes:

1.
2.
3.
4.

LUNAR EXCURSION MODULE PROPULSION SYSTEM (CODE: 03 06 01)

FUNCTION

The lunar excursion module propulsion is expected to include a descent main engine, an ascent main engine, descent reaction controls, and ascent reaction controls. Both main engines will probably be gimbaled.

Both main engine systems and both reaction control systems will use hypergolic propellants consisting of a 50-50 combination of UDMH and N_2O_4. The descent main engine must have a throttle capability.

(A Grumman report is in the process of being passed through official channels and should be available for the next report.)

PRIME CONTRACTOR

Grumman Aircraft Engineering Corporation

MAJOR CONTRIBUTORS TO UNRELIABILITY

Because of the frequency with which reaction controls are used and the small value of the impulse required, it is impractical to use ullage rockets to seat propellants prior to expulsion. Instead, a bladder is used to expel the propellants. Because the bladder is in continuous contact with the propellants, it undergoes degradation prior to use and is therefore a major source of unreliability. In addition to this difficulty, the bladder is likely to be sufficiently permeable to permit back diffusion of hypergolic propellants leading to upstream mixing of oxidizer and fuel which could explode and rupture the lines used to pressurize the bladders.

It is to be hoped that the use of bladders in the main propulsion systems can be avoided. However, the continuous burn characteristic of the main engines will cause burnthrough failure hazards to which the intermittently burning reaction control engines will not be as easily susceptible.

Valve seat material in both the main engine systems and reaction controls will be a source of difficulty to the corrosive nature of hypergolic propellants.

RELIABILITY TRENDS

Very little improvement can be expected on state-of-the-art equipment since the law of diminishing returns has already been approached. However, a breakthrough in providing improved material for bladders and valve seats would help materially. The predictions themselves can be expected to change considerably as more and better test and flight data become available.

STATE-OF-THE-ART PROPULSION RELIABILITY

The reliability block diagram used in Figure 17-4 is intended to be used for illustrative purposes. The reliability number derived is for a single start-run-shut down sequence. It is based on the observed reliabilities of similar propulsion systems which have been debugged and which use well-developed components and therefore represents "state-of-the-art". The actual configurations will undoubtedly have a different reliability because of different operating modes and improved redundancy. The latter two factors will partially offset each other.

STATE-OF-THE-HARDWARE PROPULSION RELIABILITY

A reliability prediction model based on exact engineering configuration is being prepared as rapidly as possible within the present information limitations.

RELIABILITY DOCUMENTATION

Functional Subsystem: Lunar Excursion Module Propulsion (03 06 01)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Notes:

1.
2.
3.
4.

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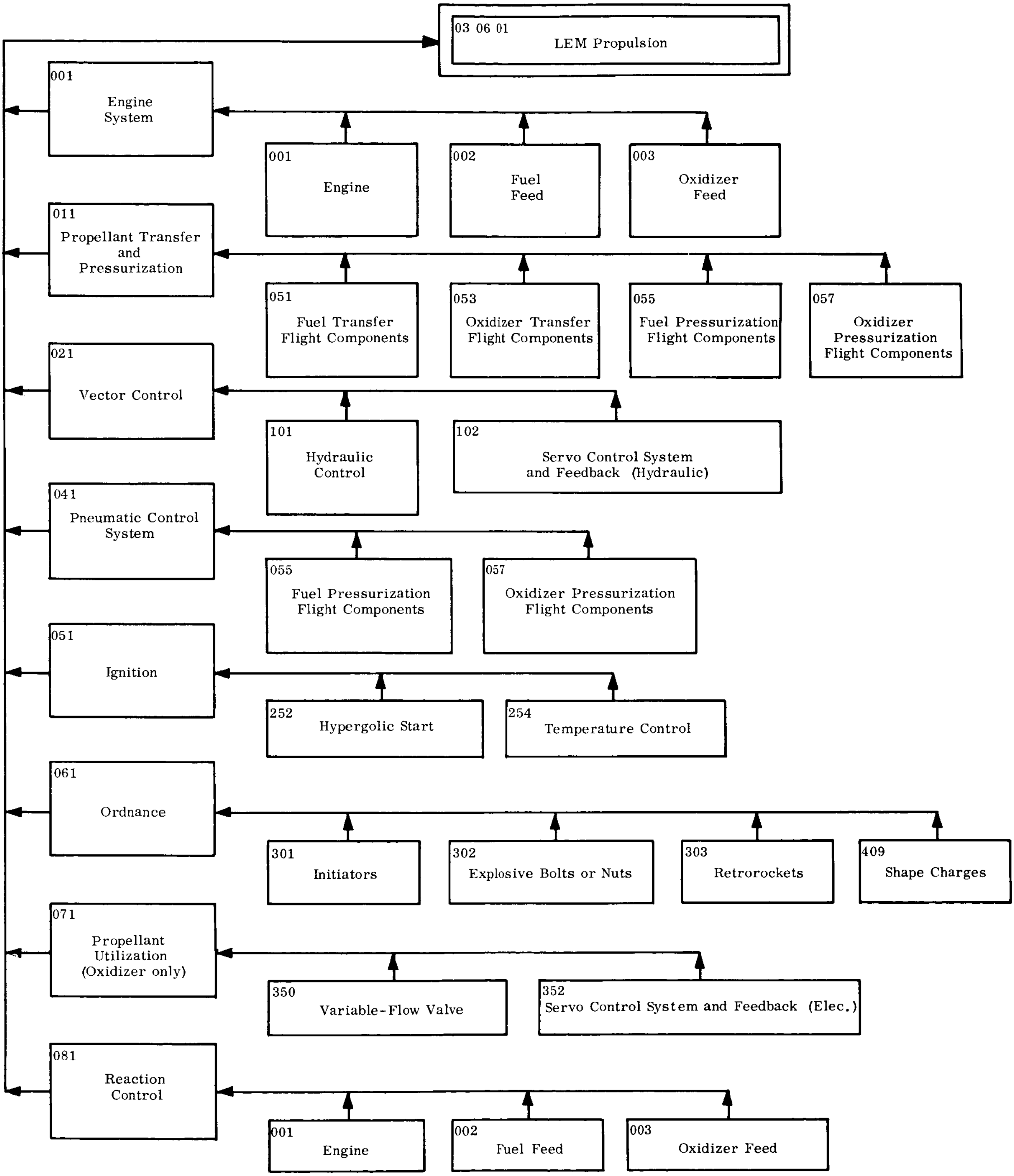


Figure 17-4. State-of-the-Art Model

Lunar Excursion Module Electrical Power System

RELIABILITY: Allocated ● Predicted o Achieved x

RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
DC Power	101						
AC Power	111						
Distribution	121						
Cabling	131						
Interstaging	141						
Lighting	151						

Notes:

1.
2.
3.
4.

LUNAR EXCURSION MODULE ELECTRICAL POWER SYSTEM (CODE: 03 06 02)

FUNCTION

The lunar excursion module electrical power system must function for an extended period to provide ac and dc outputs for many critical systems. The lunar excursion module system, like the CM/SM system, consists of both batteries and fuel cells. It provides for the normally predicted loads as well as emergency modes of operation to allow safety in abort situations.

The lunar excursion module electrical power system is not adequately defined in the presently available information. Data from a number of proposals and studies have been used to provide most probable values for reliability studies.

RELIABILITY DOCUMENTATION

Functional Subsystem: Lunar Excursion Module Electrical Power (03 06 02)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Notes:

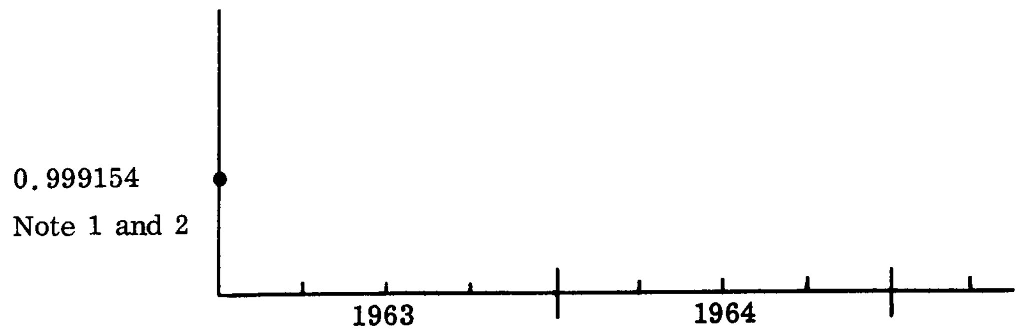
1.
2.
3.
4.

LUNAR EXCURSION MODULE STRUCTURES (CODE: 03 06 03)

Predicted Reliability: 0.999994.

Lunar Excursion Module Enviornmental Control System

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
O_2 Supply	311						
Water System	316						
Pressure Suit	321						
Back Pack	326						
Atmosphere Conditioning	331						

Notes:

1. Success estimate; Crew safety: 0.9999
2. NAA 62-557-4
3.
4.

LUNAR EXCURSION MODULE ENVIRONMENTAL CONTROL SYSTEM (CODE: 03 06 04)

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RELIABILITY DOCUMENTATION

Functional Subsystem: Lunar Excursion Module Environmental Control (03 06 04)

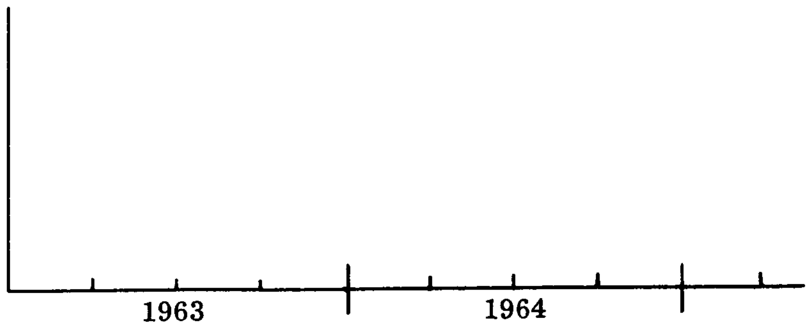
	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Notes:

1.
2.
3.
4.

Lunar Excursion Module Guidance and Navigation System

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Inertial Measurement Unit		Not Available	Not Available				
Power and Servo Assem Assembly		Not Available	Not Available				
Coupling Display Units		Not Available	Not Available				
Telescope		Not Available	Not Available				
Radar Altimeter		(1)	(1)				
Tracking Radar							
Displays and Controls							
Guidance and Navigation		0.992183 (2)	~0.96 (3)				

Notes:

1. A LEM Guidance and Navigation reliability allocation at this hardware level has not been submitted.
2. GAEC LPR-550-1 First Quarterly Reliability Status Report.
3. Independent estimate using GAEC component part failure rates from LPR-550-1.
4.

LUNAR EXCURSION MODULE GUIDANCE AND CONTROL (CODE: 03 06 05)

FUNCTION

The guidance and control functions are accomplished by two interconnected systems, the guidance and navigation system, and the stabilization and control system. The integrated system, with crew participation, determines and directs all translational and rotational velocity changes required of the lunar excursion module to accomplish the mission.

The guidance and navigation system determines lunar excursion module position and velocity, calculates velocity changes required to adhere to the flight plan, and issues steering commands to the stabilization and control system to accomplish these velocity changes.

The stabilization and control system accepts translational and rotational commands from the guidance and navigation system or from the manual controls, and directs the primary propulsion thrust vector and/or the reaction jets as required. In the absence of such commands, the system stabilizes the lunar excursion module attitude orientation by reaction jet control.

See Figure 17-5 for a block diagrammatic representation of the LEM guidance and control function.

CONTRACTORS

Guidance and Navigation: MIT Instrumentation Laboratory
Stabilization and Control: to be supplies (RCA, Autonetics, and others)

MAJOR CONTRIBUTORS TO UNRELIABILITY

GUIDANCE AND NAVIGATION

The guidance computer, the tracking radar, and the power and servo assembly are currently considered to be reliability problems, due to their large numbers of component parts and long operating times in the mission (certain radar components have also exhibited high failure rates). These subsystems are designed for inflight maintenance. Studies are in progress to discover whether inflight maintenance is sufficient or whether other alternatives for reliability improvement are indicated.

The same comments on the guidance computer and the power and servo assembly that are made on the command module guidance and navigation system also apply here since the two systems are largely identical and interchangeable. The tracking radar is also being designed for inflight replacement of high-failure-rate components.

STABILIZATION AND CONTROL

The SCS must function throughout the mission, in several modes of operation, and is essential in the interest of crew safety to a successful abort. Accordingly, the entire system is designed for inflight maintenance, and studies are underway to ascertain that this concept will yield the extremely high reliability required.

The SCS also includes a relatively simple guidance subsystem designed to back up the primary guidance and navigation system for abort during descent to the lunar surface, and for ascent guidance from the lunar surface, if required. The need for redundancy and inflight maintainability in this subsystem is currently under study, as is its contribution to over-all guidance and navigation reliability.

RELIABILITY DOCUMENTATION

Functional Subsystem: Lunar Excursion Module Guidance and Navigation

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		Not Applicable
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Notes:

1. Current GNS data derived from MIT/IL reports.
2.
3.
4.

Lunar Excursion Module
Guidance and Control

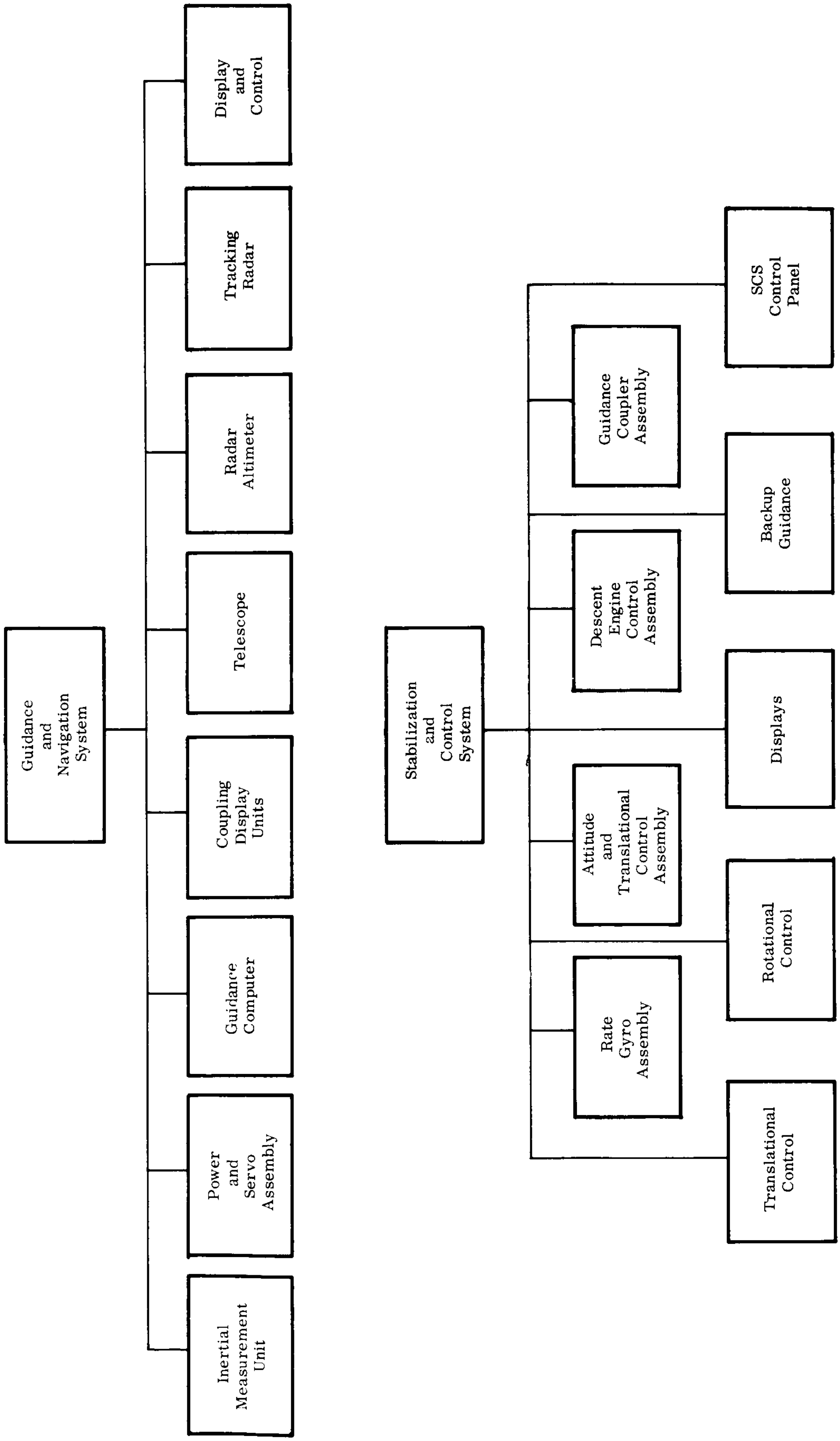


Figure 17-5. LEM Guidance and Control

RELIABILITY DOCUMENTATION

Functional Subsystem: Lunar Excursion Module Stabilization and Control

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		Not Applicable
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Notes:

1. Current SCS data derived from GAEC LPR-550-1.
2.
3.
4.

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Lunar Excursion Module Stabilization and Control System

RELIABILITY: Allocated ● Predicted o Achieved x

RELIABILITY

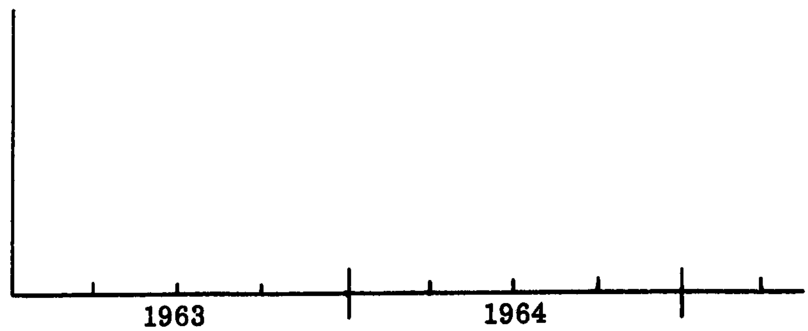
Subsystems	Code	Center Submittal: Allocated	Center Submittal: Predicted	Center Submittal: Achieved	Industry: Best	Industry: Average	Notes
Rate Gyro Assy.		0.993896					(1)
Att. & Trans. Cont. Assy.		0.998405					(1)
Guid. Coup. Assy.		0.999984					(1)
Translat. Cont.		0.999946					(1)
Rotat. Cont.		0.999946					(1)
Des. Eng. Cont. Assy.							(2)
Backup Guid.		0.998569					(1)
Displays		0.999982					(1)
SCS Cont. Pn.							(2)
S&C		0.992285					(1)

Notes:

1. GAEC LPR-550-1 First Quarterly Reliability Status Report
2. Omitted in GAEC LPR-550-1
3.
4.

Lunar Excursion Module Communications

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Audio/Visual	521						
Telemetry	531						
Tracking	511						
Instrumenta-tion	541						

Notes:

1.
2.
3.
4.

LUNAR EXCURSION MODULE COMMUNICATIONS (CODE: 03 06 06)

FUNCTION

VOICE

The communication subsystem (see Figure 17-6) is to be capable of providing voice communication between:

a. The lunar excursion module and the command module during line-of-sight phases of the mission.
b. The lunar excursion module and the earth.
c. The lunar excursion module and a crew member at a radial distance of up to three nautical miles from the lunar excursion module.
d. The crew members within the lunar excursion module.

TELEMETRY

Data transmission shall be provided on either a time shared basis with voice or transmitted simultaneously with voice.

TELEVISION

A closed-circuit television subsystem for use by the crew in monitoring the internal and external scenes in real times is to be provided. A portable near commercial quality television subsystem capable of real time and high resolution picture transmission shall also be provided with consideration given to televising the lunar excursion module launch.

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

CONTRACTORS

System: RCA

RELIABILITY DOCUMENTATION

Functional Subsystem: Lunar Excursion Module Communications (03 06 06)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis	N/A	N/A
7. Maintainability Plan - Flight		X
8. Reliability Apportionments	March 1963	
9. Reliability Model	March 1963	
10. Quarterly Reliability Reports	March 1963	
11. Test Results		X

Notes:

1.
2.
3.
4.

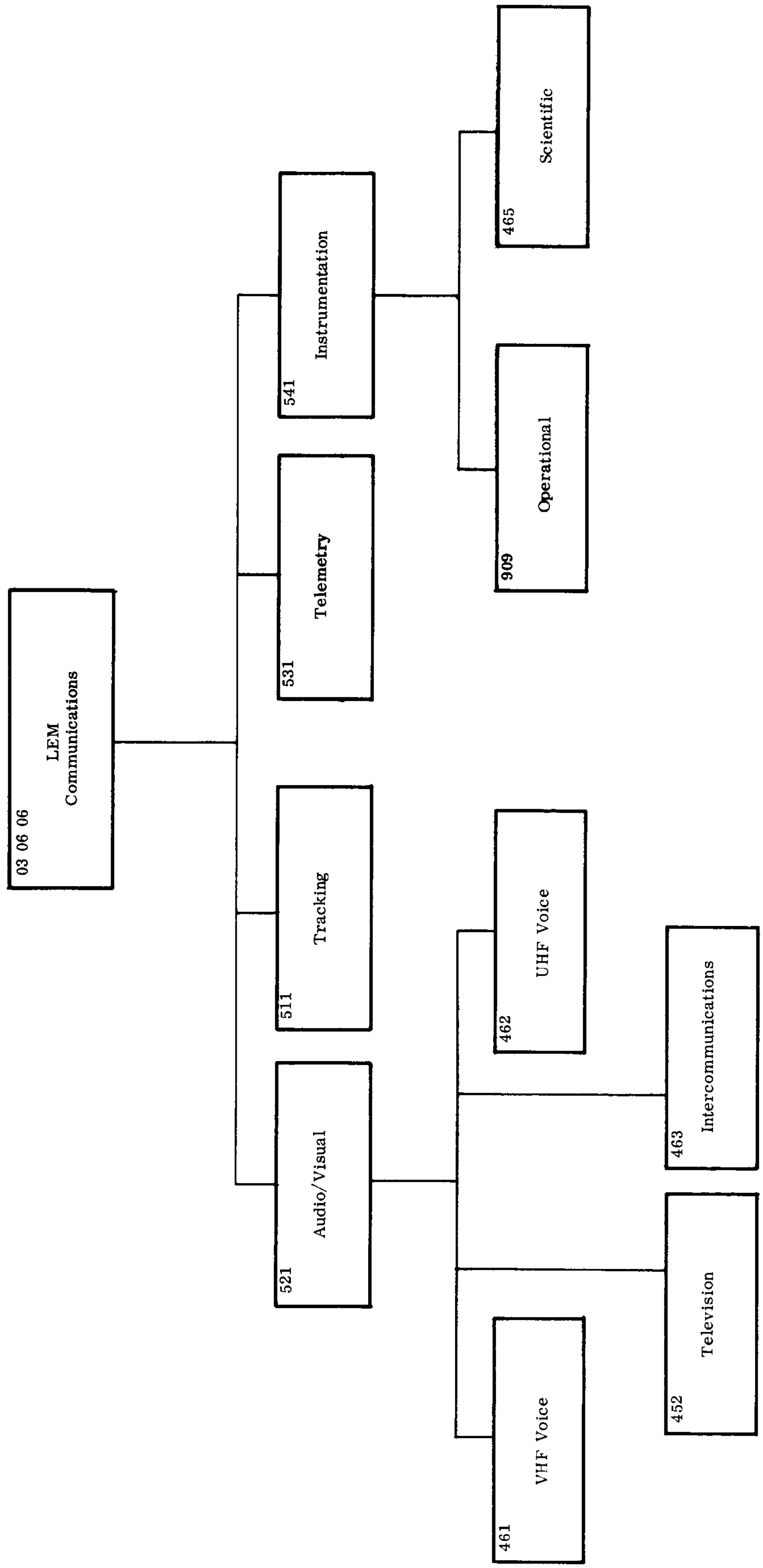


Figure 17-6. Lunar Excursion Module Communications Block Diagram

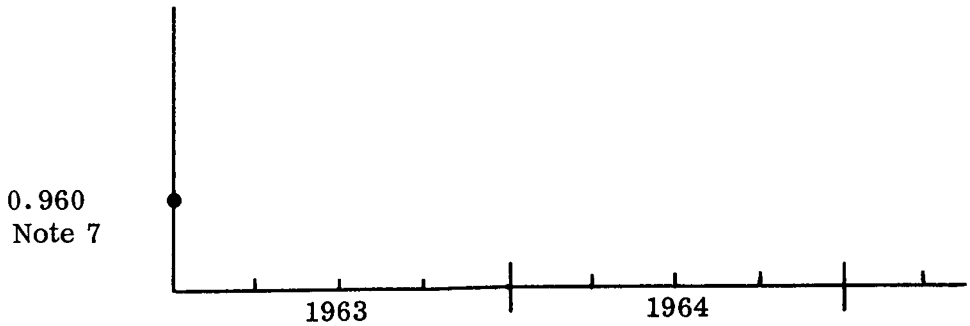
LUNAR EXCURSION MODULE CREW SYSTEM (CODE: 03 06 07)

Further definition required.

SECTION 18

SERVICE MODULE

RELIABILITY: (CM/SM) Allocated ● Predicted o Achieved x



RELIABILITY

Functional Subsystems	Code	Center Submittal			Percent of Unreliability Contributed	Notes
		Allocated	Predicted	Achieved		
Propulsion R&C System	01	0.999968	0.997833		—	2,3
Elec. Pwr.	02	0.998953	0.9941		2.0	1,2,4,6
Structures	03	0.999926	0.999947		—	3
ECS	04	0.997675	0.9805		6.7	1,6
Guidance S&C System	05	0.998901 0.994558	≅ 0.88 ≅ 0.52		27.0	1,5,6
Communications (Instrumentation)	06				—	
Crew Systems	07				—	

Notes:

1. Allocated: NAA 62-557-5
2. Allocated: NAA 62-557-4
3. Predicted: NAA 62-557-4
4. Includes CM Components in Predicted Value
5. MIT R395
6. Engineering Estimate for Illustration
7. NASw-410-61-14-01

SECTION 18

SERVICE MODULE (CODE: 03 07)

DESCRIPTION

FUNCTION

The service module (see Figure 18-1) is a major component of the spacecraft, containing the primary propulsion system and other spacecraft hardware requiring neither direct access by the crew nor use during re-entry. The communication and instrumentation subsystem is considered functionally part of the command module.

CONTRACTORS

Prime Contractor - MSC/North American Aviation
Structure - Grumman
Environmental Control - AiResearch
Electrical Power - Pratt and Whitney
Propulsion - Aerojet General
Reaction Control - Marquardt

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

Systems aboard the service module are functionally part of the command module. Their reliability must therefore be analyzed and presented in this relationship.

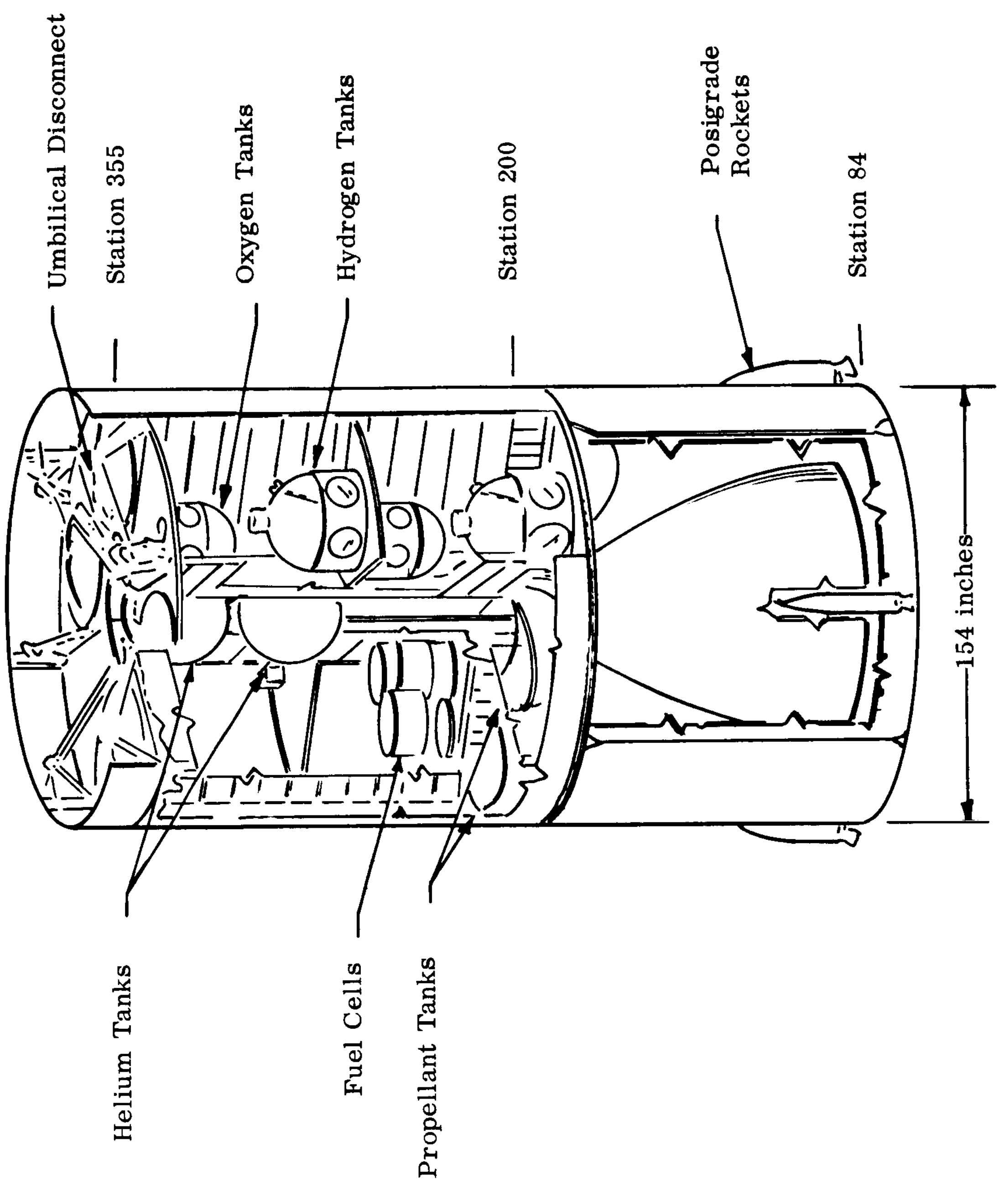


Figure 18-1. Service Module Structural Configuration

RELIABILITY DOCUMENTATION

Subsystem: Service Module

	Center Submittals Received	
	Yes	No
1. Design Specifications	1	
2. Top Drawings		X
3. Failure Effect Analysis	1	
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments	1	
9. Reliability Model	1	
10. Quarterly Reliability Reports	1	
11. Test Results		X

Notes:

1. Partial information is available, largely contained in NAA 62-557 (Quarterly Reliability Reports).
2.
3.
4.

Service Module Propulsion System

RELIABILITY: Allocated • Predicted o Achieved x

RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Engine System	001						
Propellant Transfer and Pressurization	011						
Vector Control	021						
Pneumatic Control	041						
Ignition	051						
Propellant Utilization	071						
Reaction Control	081	0.99997	0.999989				1
Ordnance	061						

Notes:

1. NAA 5th Report, page 3-74.
2.
3.
4.

PROPULSION SYSTEM (CODE: 03 07 02)

FUNCTION

The service module propulsion system includes a main engine and a reaction control engine. Both systems use the hypergolic propellant combination 50-50 UDMH/N_2O_4. The main engine uses pressure-fed propellants and is gimbaled. It has multiple restart capability and develops a nominal thrust of 21,900 pounds in vacuum. Ullage (propellant seating function) for main engine start is supplied by the reaction control engine system which uses bladder-fed propellants. The reaction control engine system is capable of operating in the continuous as well as the pulsed mode. Each reaction control system engine develops 100 pounds of thrust in vacuum.

The reaction control system is to be designed to have a complete redundant capability which includes the requirement that two of four quad engine arrangements work.

MAJOR CONTRIBUTORS TO UNRELIABILITY

One factor stands out above all others in contributing to service propulsion system unreliability. It is the use of the main engine and reaction control engine system during an extended period of time during which multiple restarts are required. The propellant-expulsion bladders used in the reaction control propulsion system are in contact with damaging propellants during the entire command module use and standby time. Valve seats in both the command module main engine system and reaction control engine system are exposed to propellants as soon as the burst diaphragms, which serve to isolate the propellant tanks from the rest of the system, are ruptured. Furthermore, it is doubtful that specific impulse requirements for the main engine can be met because of combustion instability and subsequent erosion.

RELIABILITY TRENDS

There is little reason to expect large increases in state-of-the-hardware components as compared to state-of-the-art components. However, considerable improvement can be expected as a result of design improvements which have been incorporated in the service module propulsion system. Nonetheless, it is hard to see how a crew-safety-reliability goal of 0.9998 can be achieved within the next few years. The difficulties are well-stated by the excerpts taken from Quarterly Reliability Status Report

Service Module Propulsion System

SID 62-557-5 issued on 31 May 1963 by North American, although the NAA numbers might not stand close scrutiny. This report states:

> Two major problem areas within the service module propulsion system that have become apparent are the inability of the present configuration to meet crew safety requirements and the increasing difficulty of expecting engine reliability improvement commensurate with Apollo requirements. The first was caused primarily by the change to the LOR operational concept, and the second is the inability of the subcontractor to achieve performance goals.

NAA specifically means chamber erosion and combustion instability as difficulties. Either specific impulse is low or excessive erosion occurs.

STATE-OF-THE-ART PREDICTION MODEL

A state-of-the-art prediction model is shown in Figure 18-2. It is not based on the exact hardware configuration expected but on observations of the reliability of similar systems for a single start-run-shutdown sequence. However, the requirement that only two of four quads of reaction control engines are required was taken into account.

STATE-OF-THE-HARDWARE PREDICTION MODEL

A state-of-the-hardware prediction model is being prepared as rapidly as engineering information and test stand data are made available from the centers, within the constraints imposed by manpower limitations. This model will undoubtedly predict a higher reliability figure than the state-of-the-art model but it will not meet apportioned reliability requirements. (See Figure 18-3.)

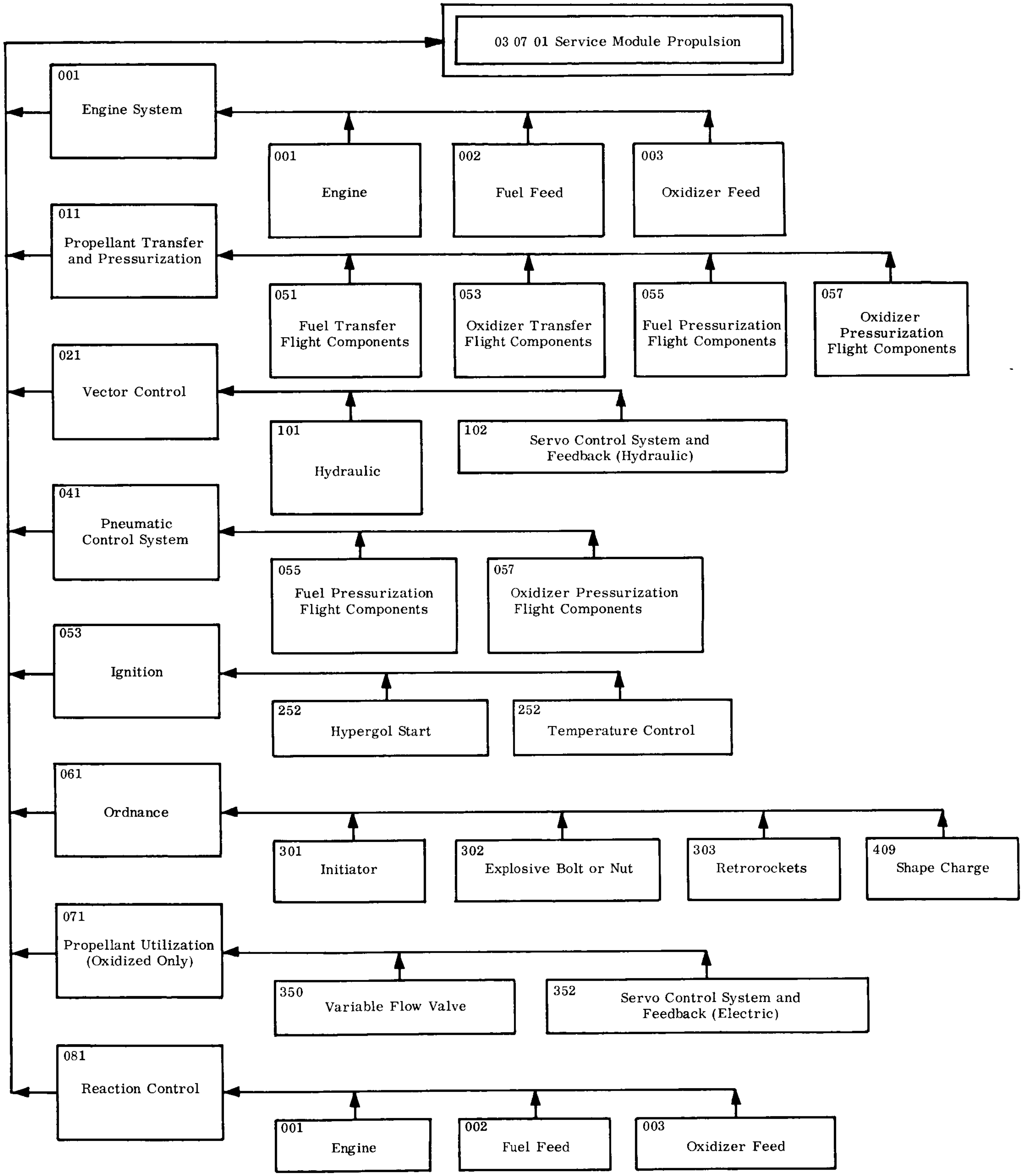


Figure 18-2. State-of-the-Art Model

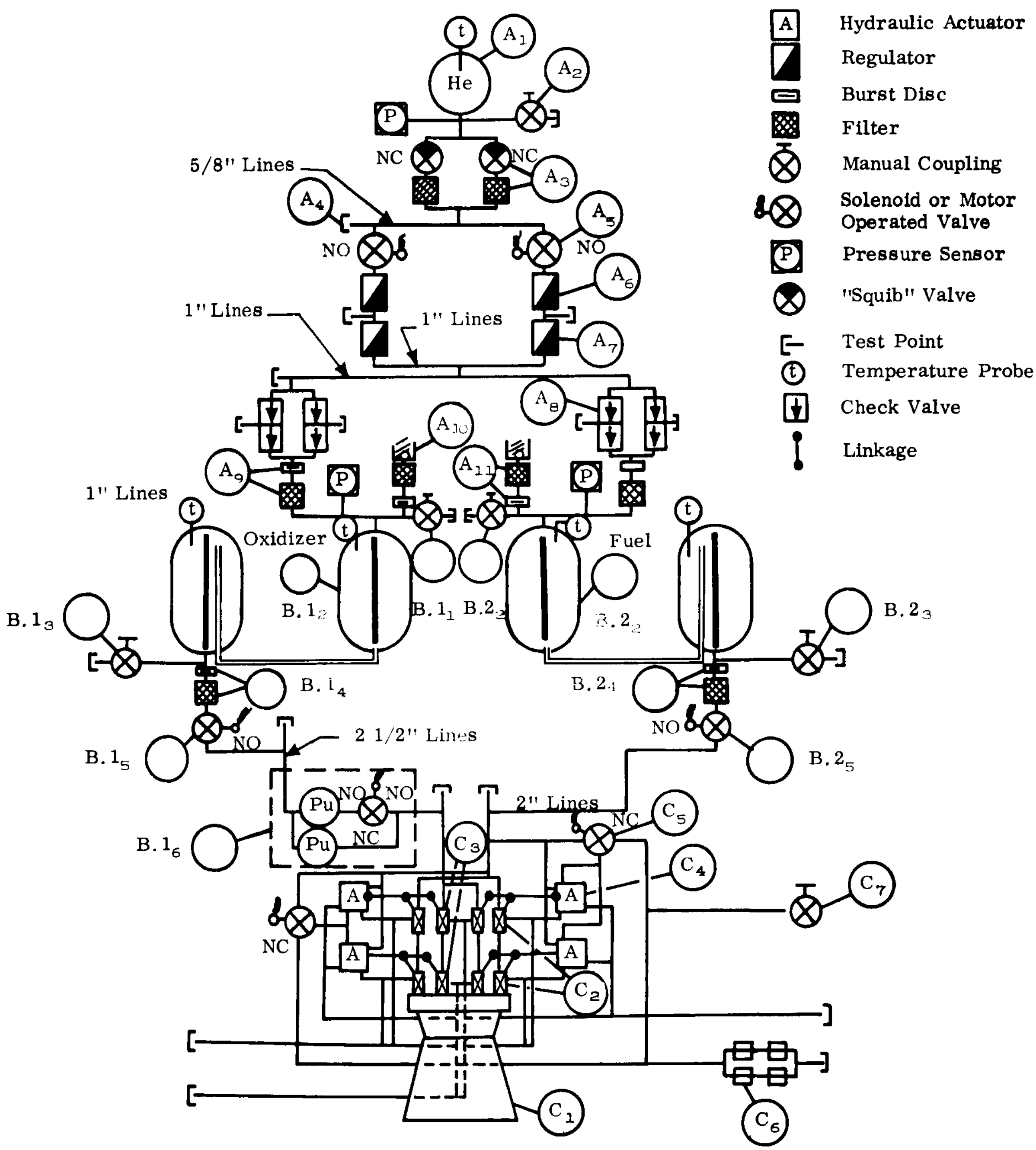


Figure 18-3. Service Module Propulsion System Schematic

RELIABILITY DOCUMENTATION

Functional Subsystem: Service Module Propulsion

	Center Submittals Received	
	Yes	No
1. Design Specifications		
2. Top Drawings		
3. Failure Effect Analysis		
4. Criticality Analysis		
5. Performance Analysis		
6. Structural Analysis		
7. Maintainability Plan		
8. Reliability Apportionments	1	
9. Reliability Model		
10. Quarterly Reliability Reports	1	
11. Test Results		

Notes:

1. These and partial coverage of other items contained in NAA 62-557.
2.
3.
4.

Service Module Electrical Power System

RELIABILITY: Allocated ● Predicted o Achieved x

RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Power Sources	116						
Distribution	121						

Notes:

1.
2.
3.
4.

SERVICE MODULE ELECTRICAL POWER SYSTEM (CODE: 03 07 02)

RELIABILITY DOCUMENTATION

Functional Subsystem: Service Module Electrical Power

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

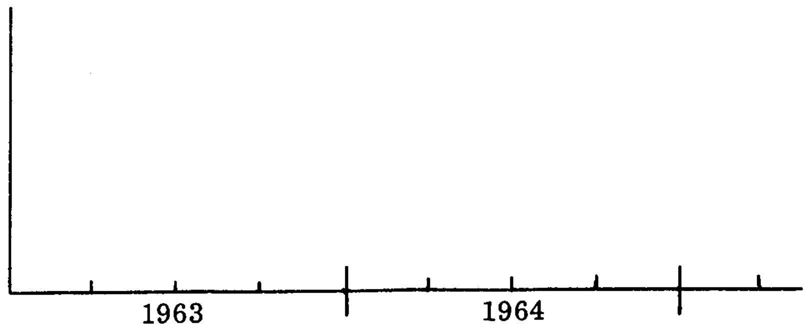
Notes:

1. Information not available as of 15 September 1963.
2.
3.
4.

SERVICE MODULE STRUCTURES (CODE: 03 07 03)

Service Module Environmental Control System

RELIABILITY: Allocated • Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
H_2O Glycol circuit	302						
O_2 Storage	306						
Radiator	307						
Water Supply	316	0.99949					1
O_2 Supply	311	0.999884					1
Radiator (Crew)	336						
Suit Control	—	0.99949					1
H_2O Glycol	—	0.999133					1

Notes:

1. NAA information; systems definition not presently identical.
2.
3.
4.

SERVICE MODULE ENVIRONMENTAL CONTROL SYSTEM (CODE: 03 07 04)

RELIABILITY DOCUMENTATION

Functional Subsystem: Service Module Environmental Control

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis	1	
4. Criticality Analysis		X
5. Performance Analysis	1	
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments	1	
9. Reliability Model		X
10. Quarterly Reliability Reports	1	
11. Test Results		X

Notes:

1. The service module system is functionally a part of the command module ECS system; documentation status is therefore similar.
2.
3.
4.

SERVICE MODULE COMMUNICATIONS (CODE: 03 07 06)

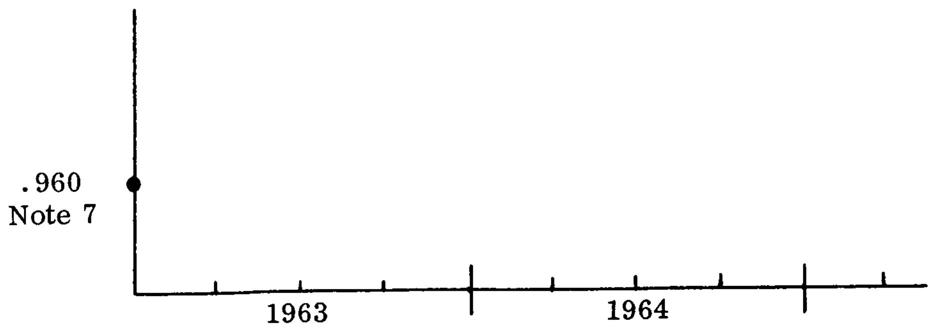
Combined with Command Module Communications, Section 19.

SECTION 19

COMMAND MODULE

Command Module Description

RELIABILITY: Allocated ● Predicted o Achieved x
(CM/SM)



RELIABILITY

Subsystems	Code	Center Submittal			Percent of Unreliability Contributed	Notes
		Allocated	Predicted	Achieved		
Propulsion RCS	01	0.000068	0.997833		——	2, 3
EPS	02	0.998853	0.9941		2.0	1, 2, 4, 6
Structures	03	0.999926	0.999947		——	3
ECS	04	0.997675	0.9805		6.7	1, 6
Guidance	05	0.998901	0.88			1, 5, 6
SCS		0.994558	0.52		27.0	
Communications (Instrumentation)	06				——	
Crew Systems	07				——	
Earth Landing		0.99994	0.99994		0.2	2, 3, 6

Notes:

1. Allocated: NAA 62-557-5
2. Allocated: NAA 62-557-4
3. Predicted: NAA 62-557-4
4. Includes SM components in predicted value.
5. MIT R395
6. Engineering estimate for illustration.
7. NASw-410-61-14-01

SECTION 19

COMMAND MODULE (CODE: 03 08)

DESCRIPTION

FUNCTION

The command module (see Figure 19-1) provides the control and communications center for the entire mission. It also houses and protects the crew. Its operation depends upon the integrated performance of all the functional subsystems listed in the reliability chart as well as portions of functional subsystems in other modules. Electrical power, communications, guidance, and the environmental control system are all related to equipment in the service module and the LEM.

CONTRACTORS

Prime Contractor - MSC/North American Aviation
Structural System - NAA
Environmental Control and Life Support - NAA/AiResearch
Electrical Power - NAA
Communications and Instrumentation - NAA/Collins
Guidance - MIT/IL: Minneapolis-Honeywell
Propulsion/Reaction Control - NAA/Marquardt

MAJOR CONTRIBUTORS TO UNRELIABILITY

Investigation to date indicates that the communications and guidance systems are the chief command module contributors to the unreliability of the mission. A major reason for the unreliability which occurs is the long period of use and number of components. Both systems have considerable backup equipment aboard the command module and in the associated systems within the service module and the LEM. The guidance and communication equipment is designed in modular form to allow a certain degree of inflight maintenance. The reliability predicted is based not only upon straight equipment functional reliability but must consider the maintainability designed into the equipment. Although the environmental control system is extremely complex and must operate for the entire mission duration, its estimated reliability is reasonably high because of the large number of available alternate modes of operation.

RELIABILITY DOCUMENTATION

Subsystem: Command Module

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis	1	
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments	1	
9. Reliability Model	1	
10. Quarterly Reliability Reports	1	
11. Test Results		X

1. Data presently available is derived largely from NAA 62-557 (Quarterly Reliability Reports) and from the Apollo System Description.

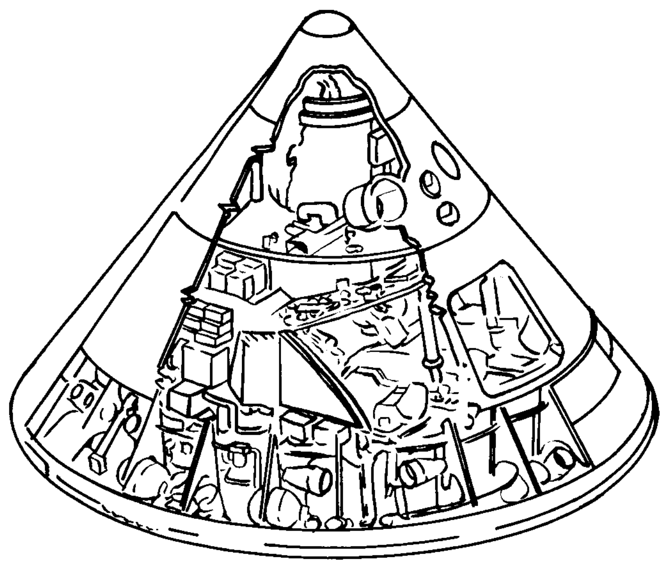
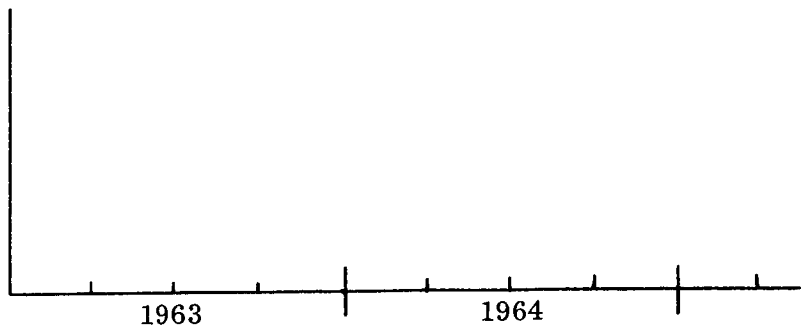


Figure 19-1. Command Module Inboard Profile

Command Module Propulsion

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Reaction Control	081	0.999960	0.999560				1
Ignition	051		0.9994				2
Pneumatic Control	041						
Ordnance	061						

Notes:

1. NAA 5th Report, page 3-63.
2. Manned No. 3 Propulsion System Reliability Estimate, page 6-2, 15 December 1962.
3.
4.

COMMAND MODULE PROPULSION (CODE: 03 08 01)

FUNCTION

The command module (see Figure 19-2) has a reaction control system only. It is to be used after jettison of the service module. It will be used for re-entry or abort to maintain attitude control. The reaction control system has a complete redundant capability.

Engines are capable of either a pulsed or a continuous mode of operation. Each engine can generate 100 pounds of thrust with a specific impulse of 300 seconds.

The propellants are 50-50 UDMH/N_2O_4 and, of course, are hypergolic and storable. They are pressure fed.

CONTRACTORS

MAJOR CONTRIBUTORS TO UNRELIABILITY

None

RELIABILITY TRENDS

STATE-OF-THE-ART RELIABILITY

Command Module Propulsion

RELIABILITY DOCUMENTATION

Functional Subsystem: Command Module Propulsion

	Center Submittals Received	
	Yes	No
1. Design Specifications		x
2. Top Drawings		x
3. Failure Effect Analysis	May 1963	
4. Criticality Analysis		x
5. Performance Analysis		x
6. Structural Analysis		x
7. Maintainability Plan		x
8. Reliability Apportionments	May 1963	
9. Reliability Model	May 1963	
10. Quarterly Reliability Reports	May 1963	
11. Test Results		x

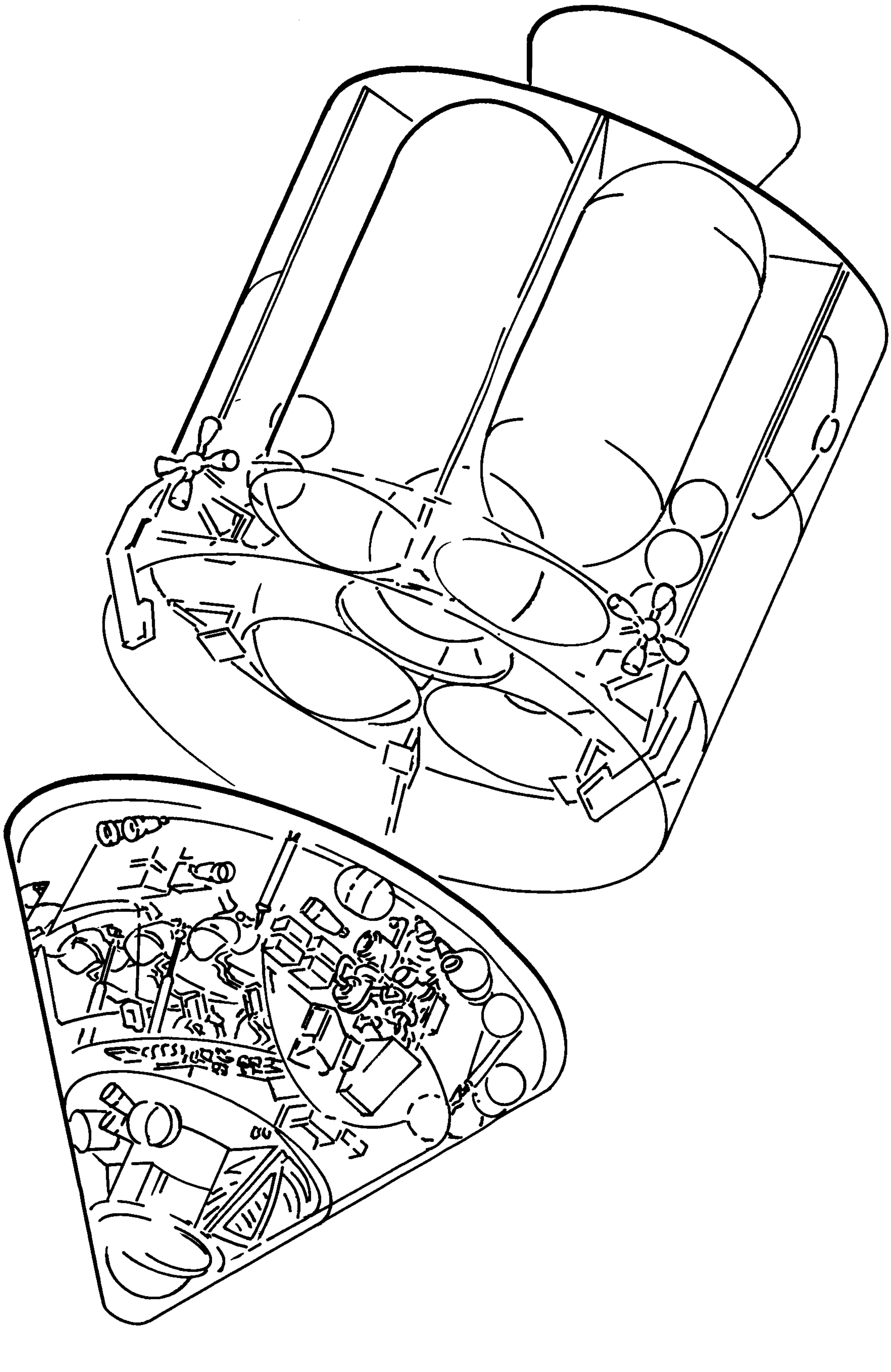
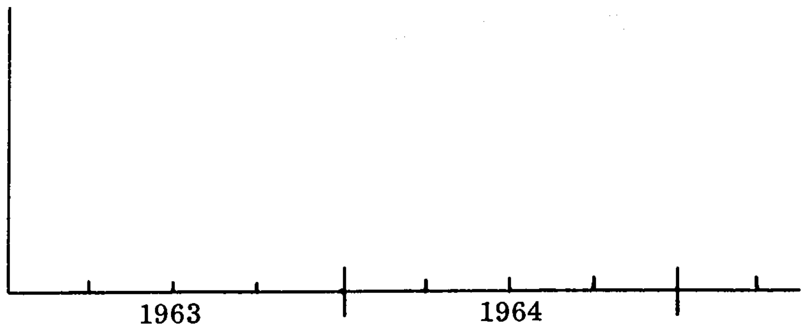


Figure 19-2. Propulsion and Recovery Systems

CM/SM Electrical Power System

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Fuel Cell		0.999553	0.994935				
Inverter		0.999737	0.999258				
Battery System		0.999993	0.999993				
DC Distributor		0.99968	0.99969				
AC Distributor		0.99999	0.999990				

Notes:

1. All data is derived from NAA 62-557-5.
2.
3.
4.

COMMAND MODULE/SERVICE MODULE ELECTRICAL POWER SYSTEM

FUNCTION

The command module/service module power system (see Figure 19-3) is an integrated but separable system for the supply of the command module electrical power demands during its mission use. Major power requirements are met by the fuel cells carried in the service module, but various batteries for specific uses supplement this power source. The service module portions of the power system function until that unit is jettisoned prior to re-entry. Thereafter, the command module power requirements are met by onboard batteries, which include units for the specific purpose of providing post landing power needs.

Requirements for alternating current power are met by inverters supplied from the dc sources. Separate distribution systems, of course, are required. See Figures 19-3 through 19-7 for additional information.

Analysis of the reliability of this system is relatively complicated for several reasons. First, the systems in the two modules are interdependent. Second, there is a wide variability in the system configurations possible by means of switching to accomplish the varied mission functions or to meet emergency abort requirements. The third and primary difficulty is in the lack of specific information. Recently available reliability analyses have shed considerable light on the system, but actual schematic and specification data still are lacking. Information supplied is, therefore, not substantiated by adequate documentation.

CONTRACTORS

Entry and Post-Landing Battery - Eagle-Picher
Battery Charger - ITT Industrial Products Division
Distribution System - NAA
CM/SM Umbilical -
S/L Sequencer - NAA
Static Inverter - Westinghouse
Interior Illumination and Advisory System - NAA
SM Electrical Distribution System - NAA
SM/GSE Umbilical -
Adapter Interface Connector -

CM/SM Electrical Power System

CM-LET Umbilical -
Forward Pressure Bulkhead Electrical Feedthrough -
Aft Pressure Bulkhead Electrical Feedthrough -
Fuel Cell Power Plants - Pratt and Whitney
Electrical Power System, LET - NAA

MAJOR CONTRIBUTORS TO UNRELIABILITY

In common with experience on previous programs, there is predictable difficulty to be encountered with the inverter systems. In view of the incomplete information now available, specific recommendations are not appropriate.

RELIABILITY TRENDS

Although some reliability predictions are available from NAA 62-557, little current information is available to provide system schematics and specifications.

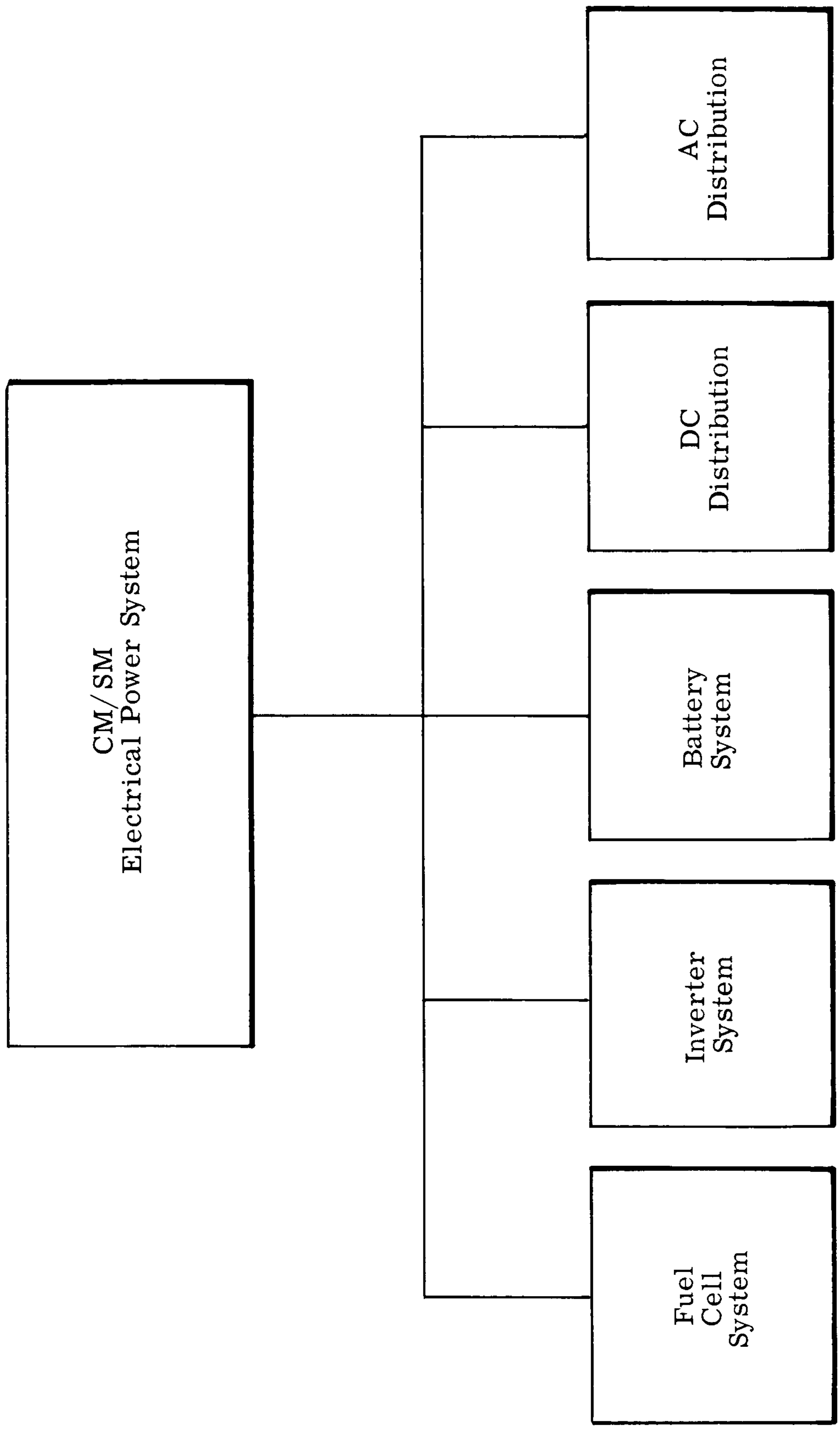


Figure 19-3. Command Module/Service Module Electrical Power System Block Diagram

Command Module Electrical Power System

RELIABILITY DOCUMENTATION

Functional Subsystem: Command Module Electrical Power

	Center Submittals Received	
	Yes	No
1. Design Specifications		2
2. Top Drawings		2
3. Failure Effect Analysis	1	
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		Not Applicable
7. Maintainability Plan		X
8. Reliability Apportionments	1	
9. Reliability Model	1	
10. Quarterly Reliability Reports	1	
11. Test Results		X

1. NAA 62-557.
2. Electrical power system specification information not available as of 15 September 1963.

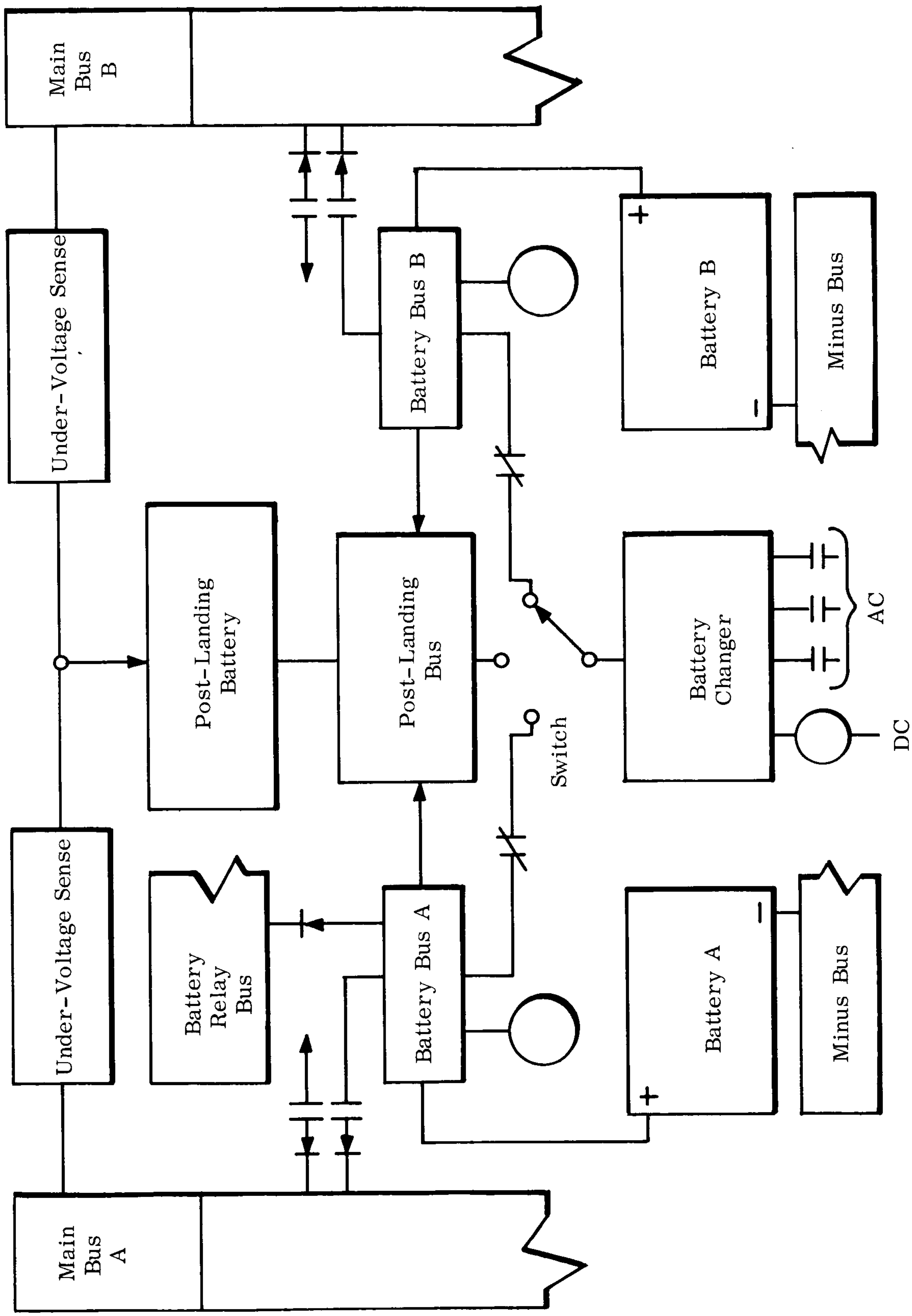


Figure 19-4. Command Module/Service Module Battery System

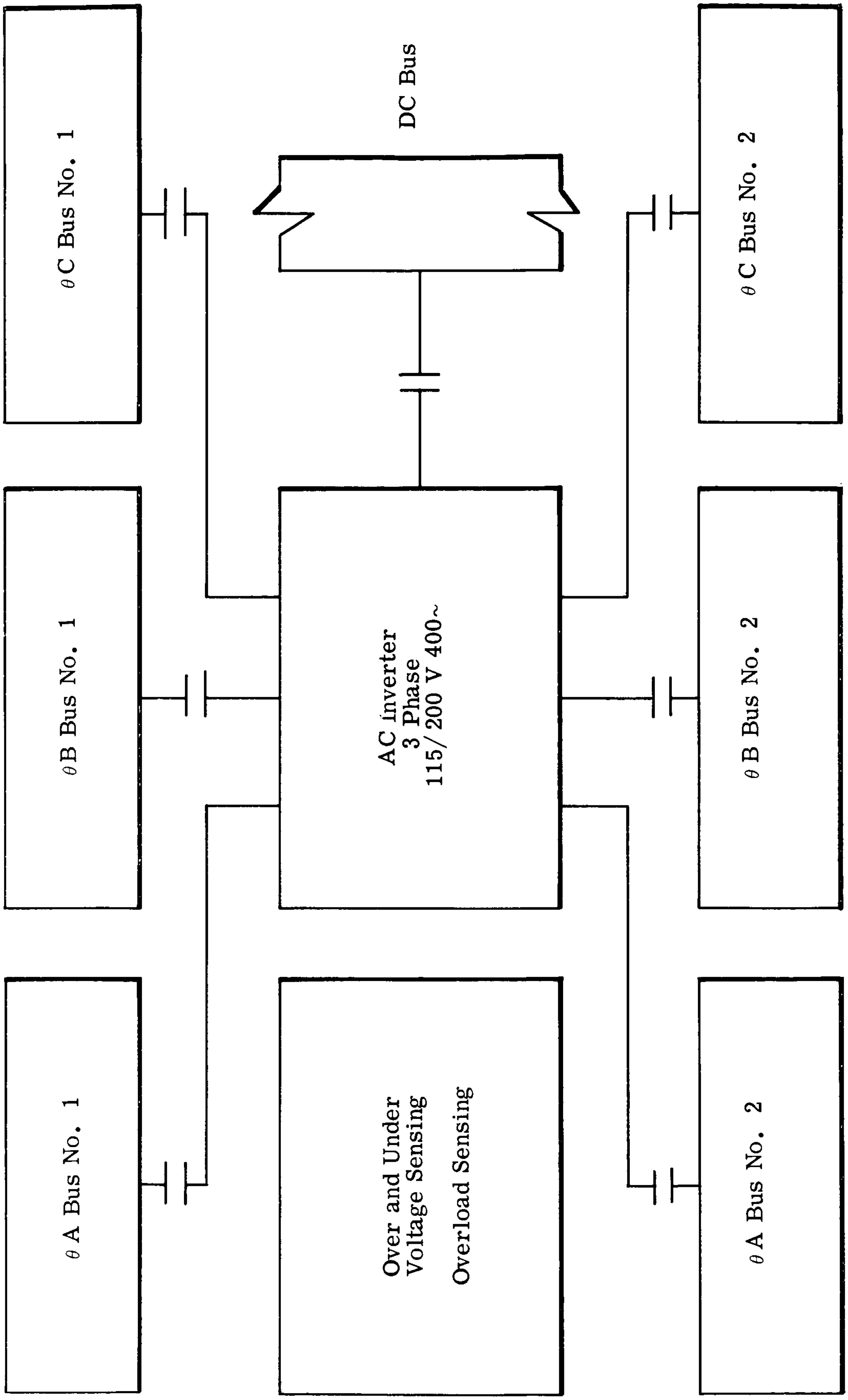


Figure 19-5. Command Module/Service Module AC Power

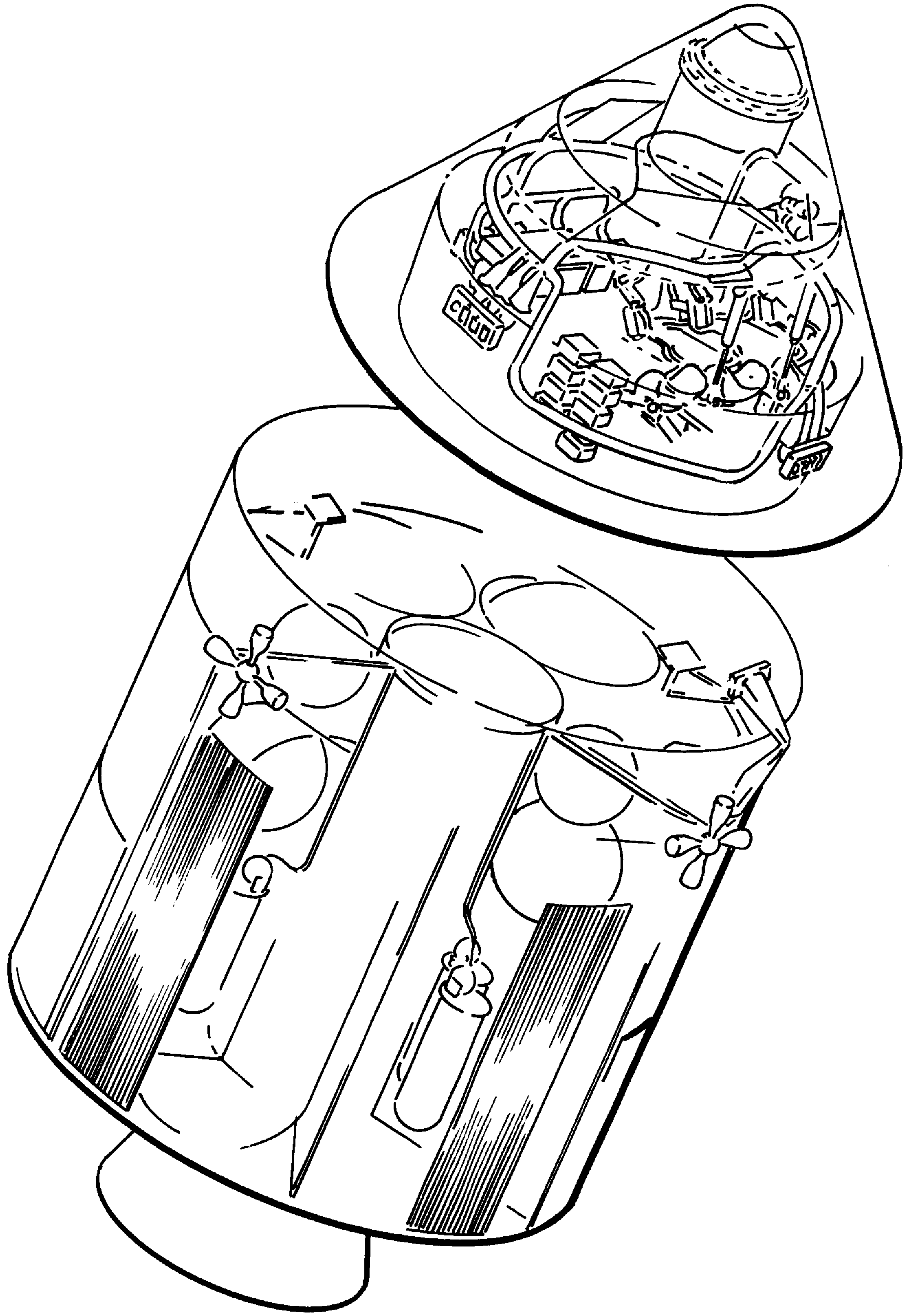


Figure 19-6. Electrical Systems

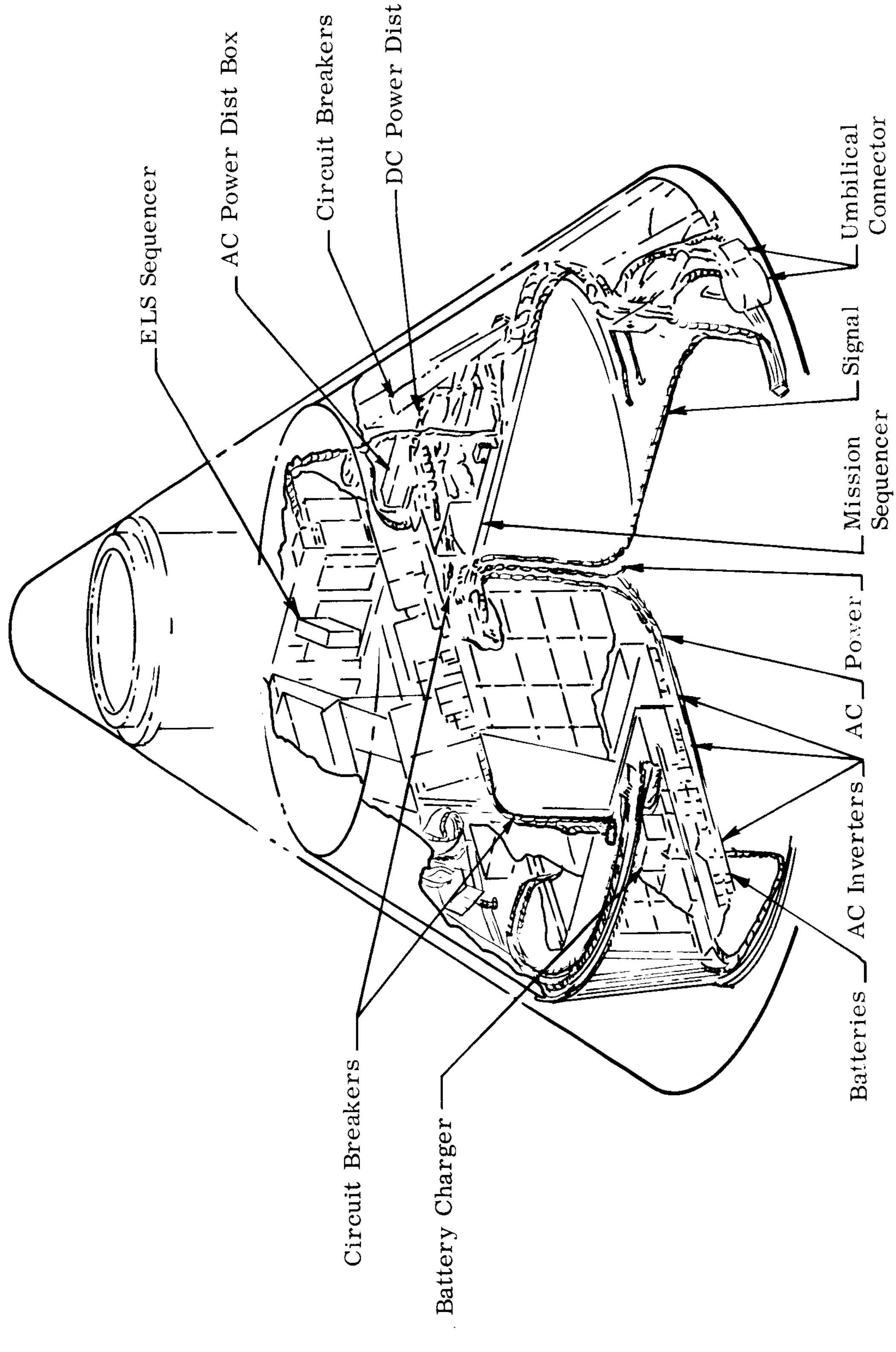


Figure 19-7. Command Module Electrical Components

COMMAND MODULE STRUCTURES (CODE: 03 08 03)

CM/SM Environmental Control System

RELIABILITY: Allocated ● Predicted o Achieved x

RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Suit Control		0.99949					
H_2O Glycol		0.999133					
Pressure and Temperature Circuit		0.999812					
O_2 Supply		0.999854					
H_2O Supply		0.99949					

Notes:

1. NAA Document 62-557-5.
2.
3.
4.

CM/SM ENVIRONMENTAL CONTROL SYSTEM (CODE: 03 08 04)

FUNCTION

The environmental control system (see Figure 19-8) will provide conditioned temperature and pressure for crew shirt-sleeve habitation of the command module and oxygen for metabolic use. The subsystem comprises five loops.

a. Suit Circuit provides oxygen for metabolic use that has been temperature-conditioned, dehumidified, and treated for removal of odors and carbon dioxide.

b. Water Glycol Circuit acts as a heat transport medium for metabolic heat generated by the crew and heat generated by onboard equipment. (Water glycol flows in a closed path from the command module to the service module where heat is rejected by space radiation, and the cool fluid is then returned to the command module where the cycle is repeated.)

c. Pressure and Temperature Circuit provides a 5-psia atmosphere to the command module interior, maintained at a temperature of approximately 70°F.

d. Oxygen Supply System supplies the command module suit circuit and pressure temperature control system with the oxygen necessary to satisfy metabolic requirements of the crew and replaces oxygen lost by command module leakage.

e. Water Management System receives and stores the potable water generated by the fuel cells as a byproduct and the metabolic waste water generated by the crew. The water stored in two tanks, potable and waste, is then available separately for consumption by the crew or for supplementary cooling during high heat loads in high thermal radiation environment.

CONTRACTORS

AiResearch

MAJOR CONTRIBUTOR TO UNRELIABILITY

RELIABILITY TRENDS

RELIABILITY DOCUMENTATION

Functional Subsystem: CM/SM Environmental Control System

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis	1	
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments	1	
9. Reliability Model		X
10. Quarterly Reliability Reports	1	
11. Test Results		X

1. Partial NAA information available.

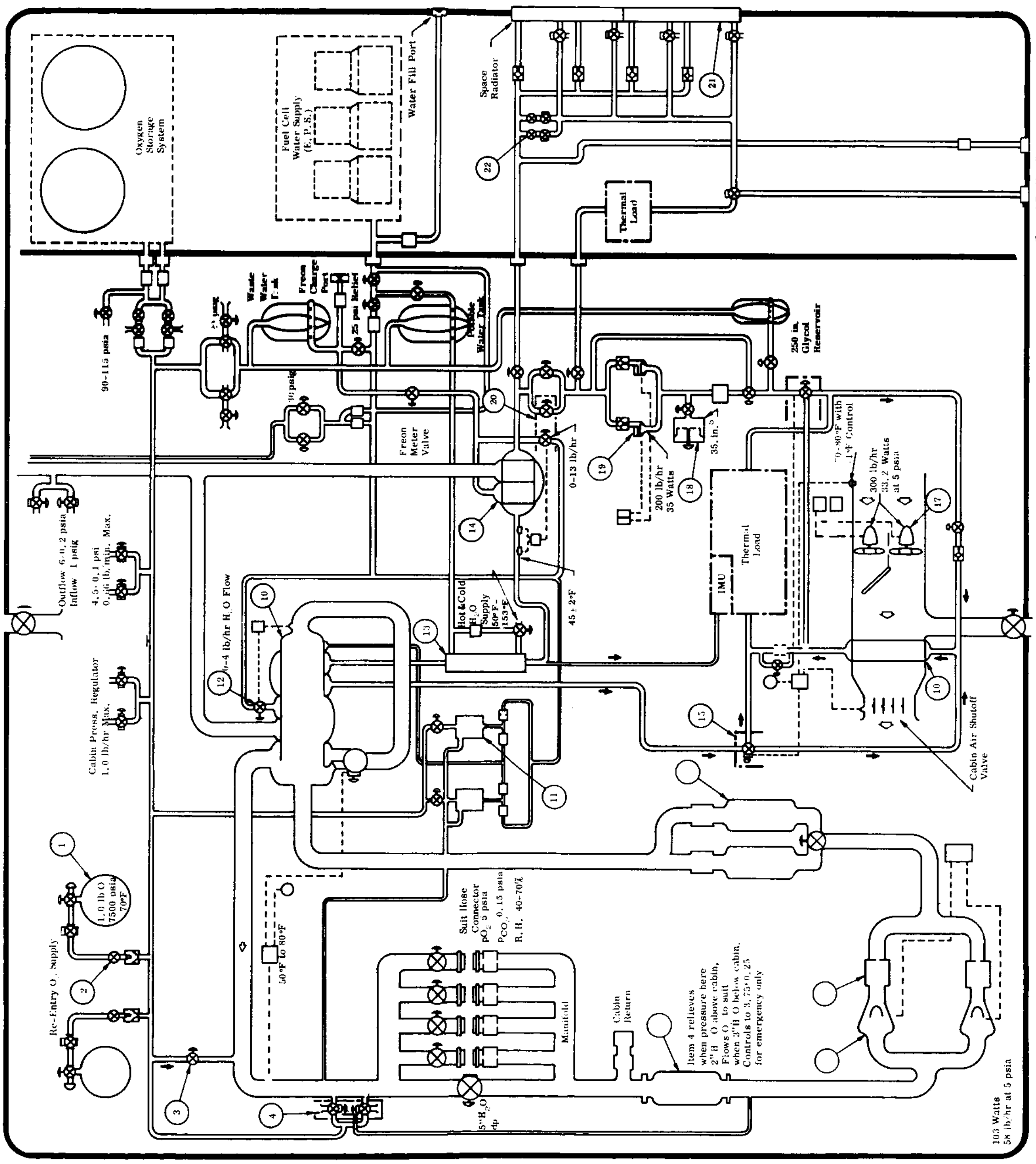
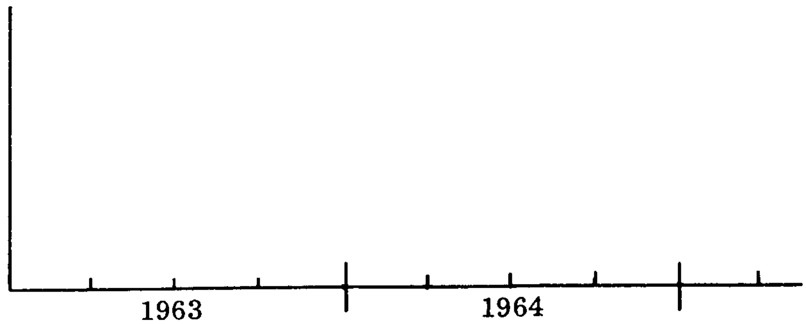


Figure 19-8. CM/SM Environmental Control System

CM/SM Communication

RELIABILITY: Allocated $\underline{\bullet}$ Predicted $\underline{o}$ Achieved $\underline{x}$



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Audio/Visual	521						
Telemetry	531	0.997	0.937				1
Instrumentation	541						
Command	501						

Notes:

1. NAA 62-557-5.
2.
3.
4.

COMMAND MODULE COMMUNICATIONS (CODE: 03 08 06)

VOICE

Two-way voice communication capability (see Figure 19-9) will be provided between the individual crew members, between the command module and earth based stations, and between each module in a rendezvous maneuver. A personal communication system will provide two-way voice communication between crew members whether internal or external to the command module. An intercommunication (plug-in) system will be supplied. Reliable communication in the near earth phase of flight shall be afforded by a UHF link to that range at which DSIF communications can be acquired and maintained for all potential flight paths. Voice communication using the UHF DSIF transponder will provide reliable voice transmission and reception to lunar distance.

TELEMETRY

A flexible pulse code modulation telemetry subsystem that is compatible with both the VHF and UHF transmission systems will be provided. Initial telemetry and display system design will be flexible enough for the addition of ground spacecraft data link.

TELEVISION

A closed-circuit television subsystem will be provided for use by the crew in monitoring internal and external scenes in real time. Optimum modulation will be used. Frame rate and resolution tradeoffs with transmitter power and antenna size will be optimized.

TRACKING TRANSPONDERS

A C-band transponder subsystem compatible with the NA/FPS-16 and equivalent radar will be provided. This subsystem will be capable of providing reliable tracking signals in the near earth phase of flight as far as the range at which DSIF tracking can be acquired and maintained for all potential flight paths. A UHF transponder that provides reliable velocity and range tracking to lunar distance when used with the DSIF will be supplied.

RADIO RECOVERY AIDS

The radio recovery aids subsystem will consist of an HF transceiver system which may be either voice or tone modulated, and a VHF beacon.

CM/SM Communications

ANTENNAS

The near-earth antenna system will consist of multiple flush-mouthed antennas which essentially provide omnidirectional patterns in a plane that is perpendicular to the booster longitudinal axis of the booster. A similar antenna compatible with DSIF will be used at minor deep space distances. This antenna will offer sufficient gain to permit the reliable transfer of priority information at a reduced bandwidth in an emergency condition up to lunar distances. The directional antenna system will be designed to withstand the stresses to which it will be subjected throughout the mission or it will be retractable for periods of high stress. Both manual and automatic antenna steering will be provided for the directional antenna.

OPERATIONAL INSTRUMENTATION

The system operational instrumentation systems will detect, measure, and display all parameter required by the crew for monitoring and evaluating the integrity and environment of the spacecraft, and the performance of the spacecraft systems. It will provide data for transmission to earth to facilitate the ground assessment of spacecraft performance and failure analysis. It will provide the crew with the information required for abort decision. This system will also document the mission through photography and tape recording.

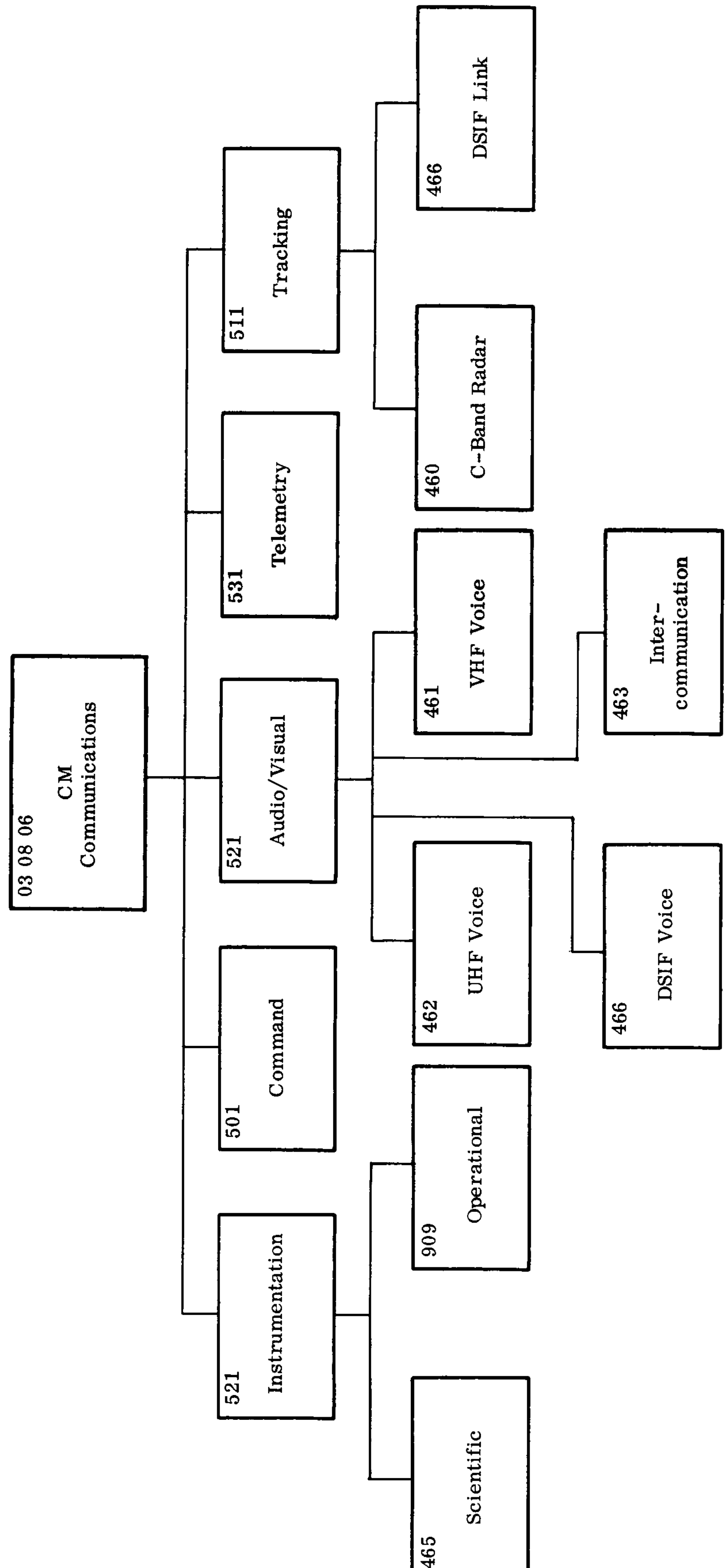


Figure 19-9. Command Module/Service Module Communication

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RELIABILITY DOCUMENTATION

Functional Subsystem: CM/SM Communications

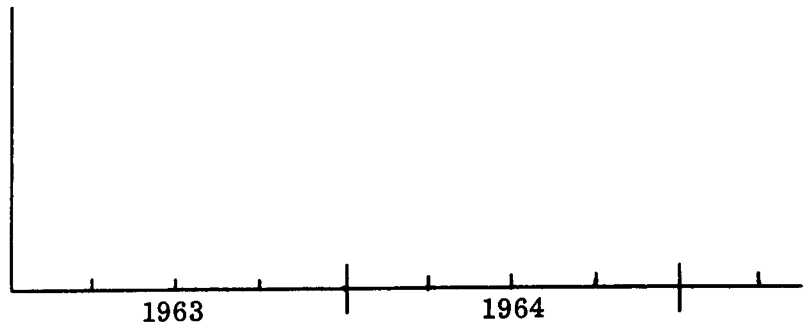
	Center Submittals Received	
	Yes	No
1. Design Specifications	Sept. 1962	
2. Top Drawings		x
3. Failure Effect Analysis	May 1963	x
4. Criticality Analysis	Sept. 1962	
5. Performance Analysis	N/A	N/A
6. Structural Analysis		x
7. Maintainability Plan		x
8. Reliability Apportionments	May 1963	
9. Reliability Model	May 1963	
10. Quarterly Reliability Reports	May 1963	
11. Test Results		x

Notes:

1. NAA 62-557 is the major source of numerical values; configuration and specification data are from the Apollo System Description.
2.
3.
4.

Command Module Crew Systems

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Personnel Protection and Support	621						
Waste Management	631						
Food and Water	641						
Personnel Hygiene, Health, and Comfort	651						
Lighting	151						
Survival Equipment	351						

Notes:

1.
2.
3.
4.

COMMAND MODULE CREW SYSTEMS (CODE: 03 08 07)

The equipment in these systems (see Figure 19-10) is as defined by NAA 62-557-5. Reliability data is not presently available. Some of the equipment is essentially identical with that contained in the LEM, and exists as a backup for these units in this arrangement.

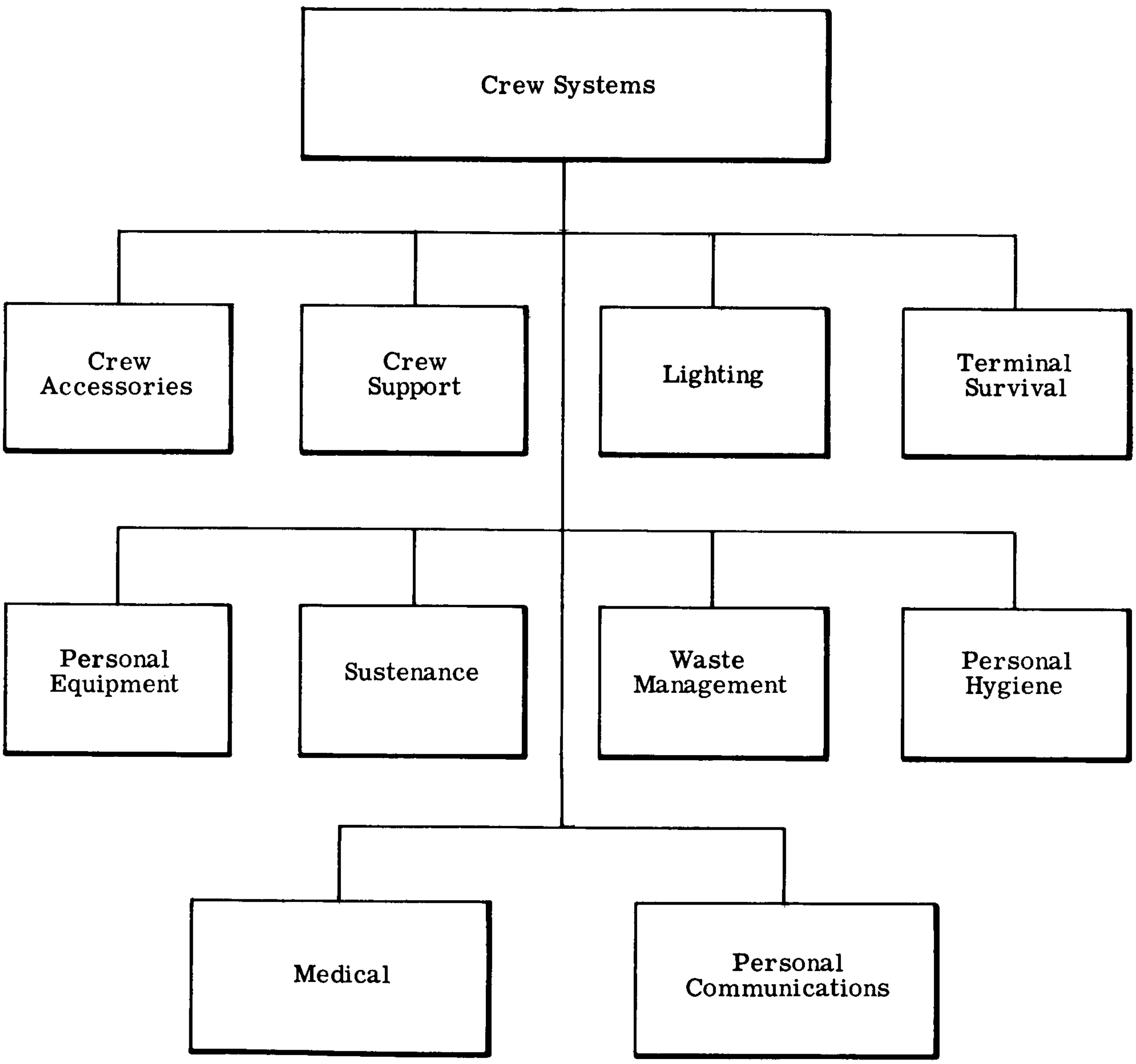


Figure 19-10. Command Module Crew Systems Block Diagram

RELIABILITY DOCUMENTATION

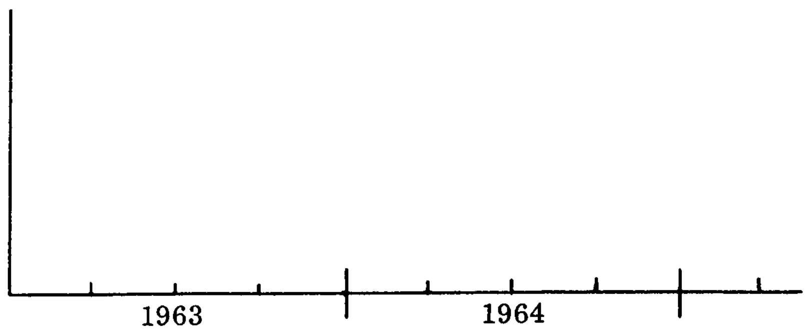
Functional Subsystem: Crew Systems

	Center Submittals Received	
	Yes	No
1. Design Specifications		1
2. Top Drawings		1
3. Failure Effect Analysis		1
4. Criticality Analysis		1
5. Performance Analysis		1
6. Structural Analysis		1
7. Maintainability Plan		1
8. Reliability Apportionments		1
9. Reliability Model		1
10. Quarterly Reliability Reports		1
11. Test Results		1

1. Partial information only.

Command Module Guidance and Navigation System

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Inertial Measurement Unit	Not Applicable	Not Applicable					
Power and Servo Assy.							
Guidance Computer							
Coupling Display Units							
Sextant							
Scanning Telescope							
Map and Data Viewer							
Displays and Controls							
G&N		0.998901[1][2]	~ 0.88[1][3]				

Notes:

1. MIL/IL Report R-395 does not allocate or predict reliability to these major subsystems, nor to the LOR mission G&N allocation.
2. NAA Report SID 62-557-5.
3. MIL/IL Report R-395.
4.

COMMAND MODULE GUIDANCE AND CONTROL

FUNCTIONS

The guidance and control functions (see Figure 19-11) are accomplished by two interconnected systems, the guidance and navigation system, and the stabilization and control system. The integrated system, with crew participation, determines and directs all translational and rotational velocity changes required of the spacecraft to accomplish the mission.

The guidance and navigation system determines spacecraft position and velocity, calculates velocity changes required to adhere to the flight plan, and issues steering commands to the stabilization and control system to accomplish these velocity changes.

The stabilization and control system accepts translational and rotational commands from the guidance and navigation system or from the manual controls, and directs the primary propulsion thrust vector and/or the reaction jets as required. In the absence of such commands, the system stabilizes the spacecraft attitude orientation by reaction jet control.

CONTRACTORS

Guidance and Navigation - MIT Instrumentation Laboratory
Stabilization and Control - Minneapolis-Honeywell

MAJOR CONTRIBUTORS TO UNRELIABILITY

GUIDANCE AND NAVIGATION

The guidance computer and the power and servo assembly are currently considered to be reliability problems, because of their large numbers of component parts and long operating times in the mission. These subsystems are designed for inflight maintenance; studies are in progress to discover whether inflight maintenance is sufficient or whether other alternatives for reliability improvement are indicated.

Based on estimates derived from part counts and current component part failure rates, the computer has a very high over-all failure rate. Since it is activated and in use throughout most of the mission, its reliability estimate is low. However, MIL/IL Report R-410 (May 1963) points out that: (1) part count failure rate estimates on similar computers have proved to be at least four times too high; (2) the Apollo computer is in an idle, low-power mode much of the time; (3) the failure rate assumed for the most critical computer components (micrologic gates) is perhaps too high; and (4) the sources of most computer failures to date, the welded-wire junctions, have not been considered. The report concludes that the computer failure rate will probably be much lower than currently estimated by part count analysis.

Certain portions of the power and servo assembly, such as the IMU temperature control electronics and the sextant and telescope electronics, are also required to operate through most or all of the mission. It is not known at this time whether anything less than the entire PSA can be activated. The large number of electronic components and welded wire junctions in the PSA result in a high estimated failure rate. The long operating time results in an inadequate level of reliability, and emphasis is being placed on inflight maintenance (replacement of faulty modules) to maintain performance throughout the mission.

Current estimates of inertial measurement unit failure rates are sufficiently low that, in view of the short duty cycle of this equipment, no reliability problems are presently anticipated.

STABILIZATION AND CONTROL

The SCS must function throughout the mission, in several modes of operation, and is essential to any successful abort in the interest of crew safety. Accordingly, the entire system is designed for inflight maintenance, and studies are underway to ascertain that this concept will yield the extremely high reliability required.

Currently, the flight director attitude indicator, the attitude gyro coupling unit in the auxiliary electronic control assembly, and the various inertial sensors are estimated to have relatively high failure rates. These components are among those being considered for inflight replacement.

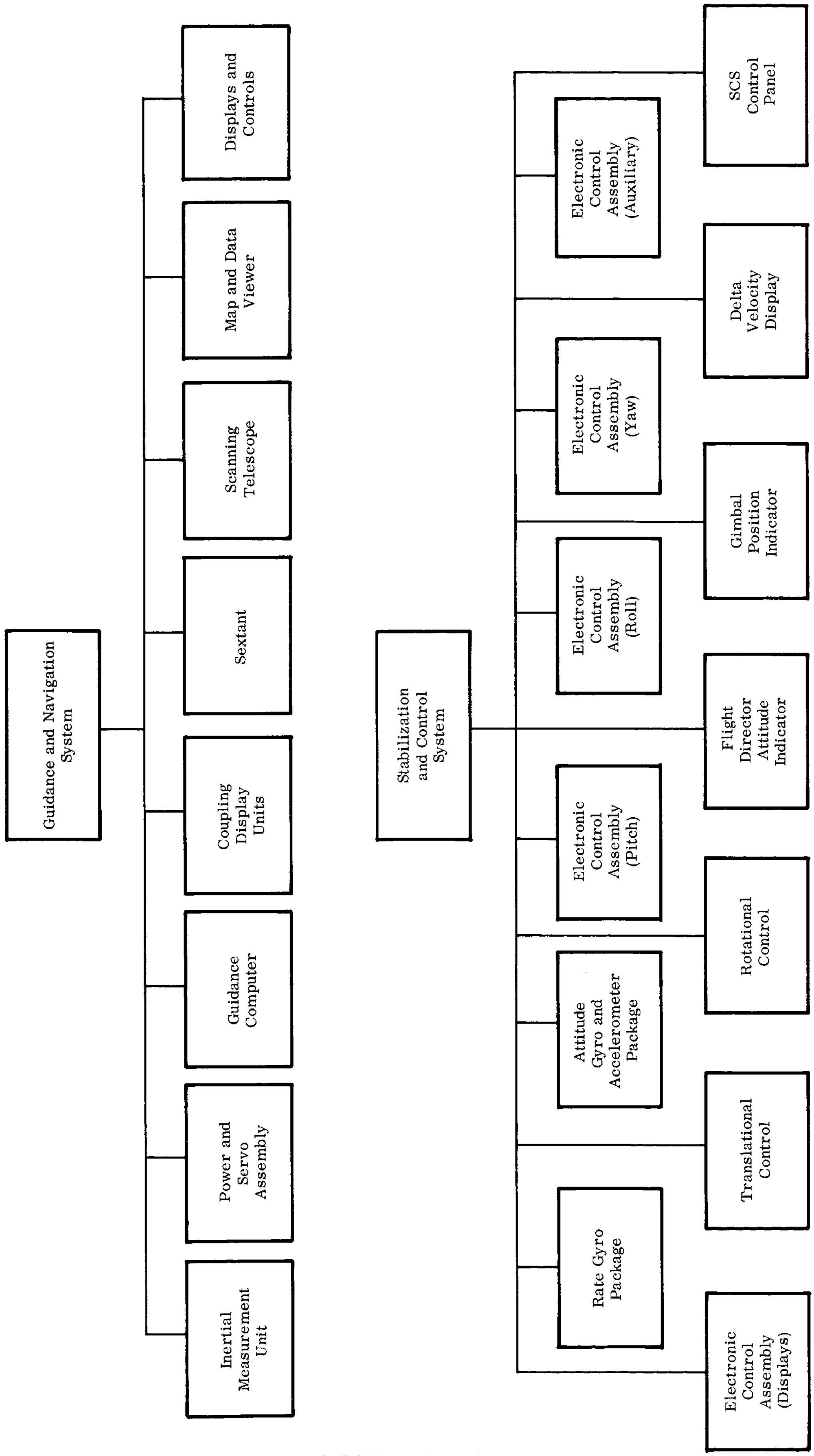


Figure 19-11. Command Module Guidance and Control

Command Module Guidance and Navigation System

RELIABILITY DOCUMENTATION

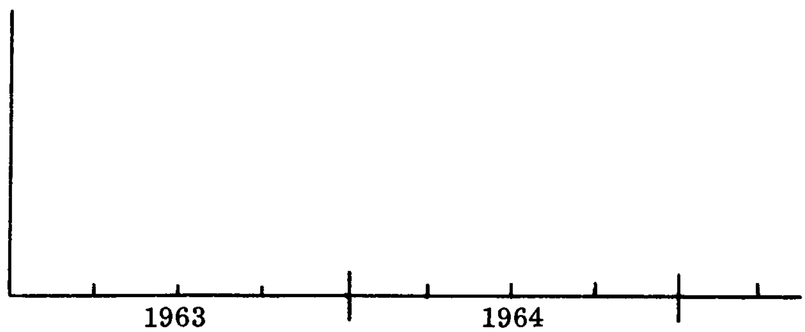
Functional Subsystem: Guidance and Navigation (CM)

	Center Submittals Received	
	Yes	No
1. Design Specifications	x	
2. Top Drawings	x	
3. Failure Effect Analysis		x
4. Criticality Analysis		x
5. Performance Analysis		x
6. Structural Analysis		Not Applicable
7. Maintainability Plan		x
8. Reliability Apportionments		x
9. Reliability Model		x
10. Quarterly Reliability Reports		x
11. Test Results		x

Notes:

1. Current GNS data derived from several MIL/IL, ACSP, and Raytheon reports acquired from OMSF library. No MIT/IL or industrial subcontractor documentation submitted by centers.
2.
3.
4.

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

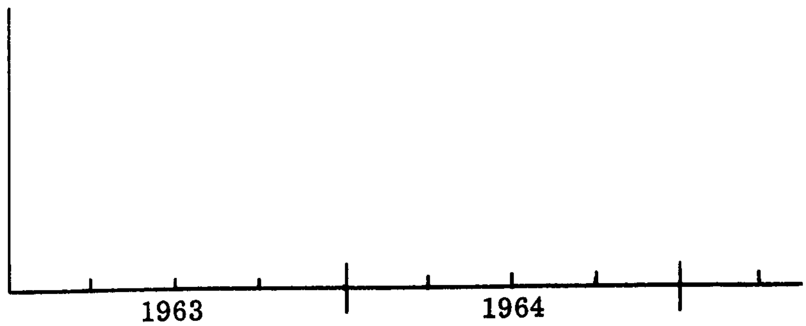
Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Rate Gyro Package		Not Available (1)	0.949804				2
Attitude Gyro and Accelerometer Package			0.917961				3
ECA (Pitch)			0.985210				2
ECA (Roll)			0.985210				2
ECA (Yaw)			0.985210				2
ECA (Aux.)			0.913838				3
ECA (Display)			0.994381				3
Translational Control			0.999999				2
Rotational Control			0.999999				2

Notes:

1. M-H had not allocated reliability to this equipment level as of 20 July 1963.
2. NAA SID 62-557-5.
3. Synthesized from component assembly reliabilities found in SID 62-557-5.
4.

Command Module Stabilization and Control System

RELIABILITY: Allocated • Predicted o Achieved x



RELIABILITY (CONT.)

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Flight Director Attitude Indicator		Not Available	0.701594				2
Gimbal Position Indicator			0.999884				2
Delta Velocity Display			0.999056				2
SCS Control Panel			0.980885				2
Stabilization and Control		0.994558	~ 0.52				

Notes:

1. M-H had not allocated reliability to this equipment level as of 20 July 1963.
2. NAA SID 62-557-5.
3. Synthesized from component assembly reliabilities found in SID 62-557-5.
4.

RELIABILITY DOCUMENTATION

Functional Subsystem: Stabilization and Control

	Center Submittals Received	
	Yes	No
1. Design Specifications		x
2. Top Drawings		x
3. Failure Effect Analysis		x
4. Criticality Analysis		x
5. Performance Analysis		x
6. Structural Analysis		Not Applicable
7. Maintainability Plan		x
8. Reliability Apportionments		x
9. Reliability Model		x
10. Quarterly Reliability Reports		x
11. Test Results		x

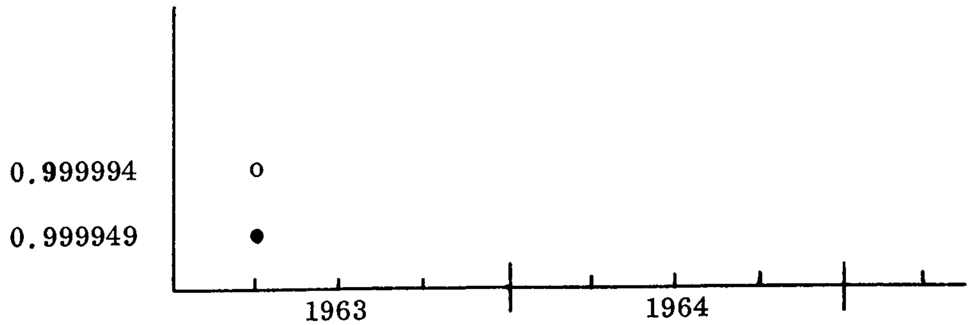
1. Current SCS data derived from NAA SID 62-557-5 acquired from OMSF library. No Honeywell or NAA-SCS documentation was submitted by the centers.

SECTION 20

LAUNCH ESCAPE SYSTEM

Launch Escape System Description

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Percent of Unreliability Contributed	Notes
		Allocated	Predicted (1)	Achieved		
Initiator (hot wire squib)		0.999	0.999			
Launch escape motor		0.998	0.993		3.5	4
Pitch control motor		0.999	0.9992			2
Tower jettison motor		0.99995	0.9998			
Tower structure		0.99999	0.999999			
Tower separation mechanics (explosive bolts)		0.99999	0.999999			
Total System		0.999949	0.999994			

Notes:

1. Based on state-of-the-art failure rates.
2. Not required for mission success.
3. All data from NAA Document SID 62-557-5.
4. Contributed unreliability is for entire launch escape system; value shown is estimate for illustration only.

SECTION 20

LAUNCH ESCAPE SYSTEM
(CODE: 03 09)

DESCRIPTION

The launch escape system is used to provide a means for crew escape during the initial boost phase of the launch vehicle when required by launch vehicle failure. It is attached to the command module and is jettisoned immediately after the second boost phase is entered (the second phase is entered by passing through the region of maximum dynamic pressure of gravity). Successful jettison of the launch escape system is a prerequisite for mission success and its probability is therefore included in the success model. (See Figures 20-1 and 20-2.)

CONTRACTORS

PRINCIPAL CONTRIBUTORS TO UNRELIABILITY

RELIABILITY TRENDS

It seems unlikely that reliability apportionments for the solid propellant rockets can be met. All other problems are expected to be solved during debugging operations.

The notable criticality of the problems encountered is not to be underestimated. The problems are, however, ones whose solutions are expected.

RELIABILITY DOCUMENTATION

Functional Subsystem: Launch Escape System (Code: 03 09)

	Center Submittals Received	
	Yes	No
1. Design Specifications		
2. Top Drawings		
3. Failure Effect Analysis	1	
4. Criticality Analysis		
5. Performance Analysis		
6. Structural Analysis		
7. Maintainability Plan		
8. Reliability Apportionments	1	
9. Reliability Model	1	
10. Quarterly Reliability Reports	1	
11. Test Results		

Notes:

1. Partial information available from NAA 62-557.
2.
3.
4.

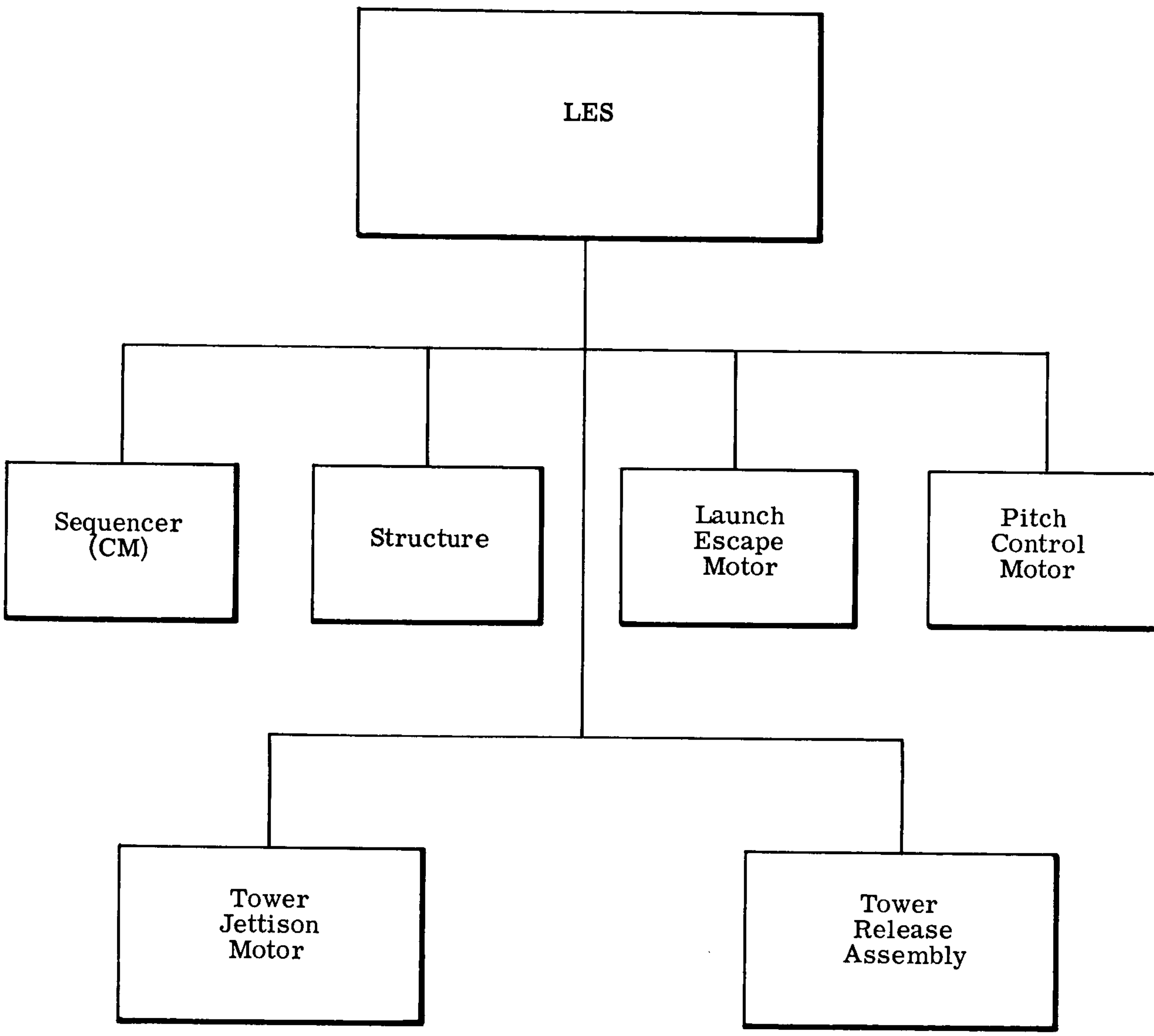


Figure 20-1. Launch Escape System Functional Flow Diagram

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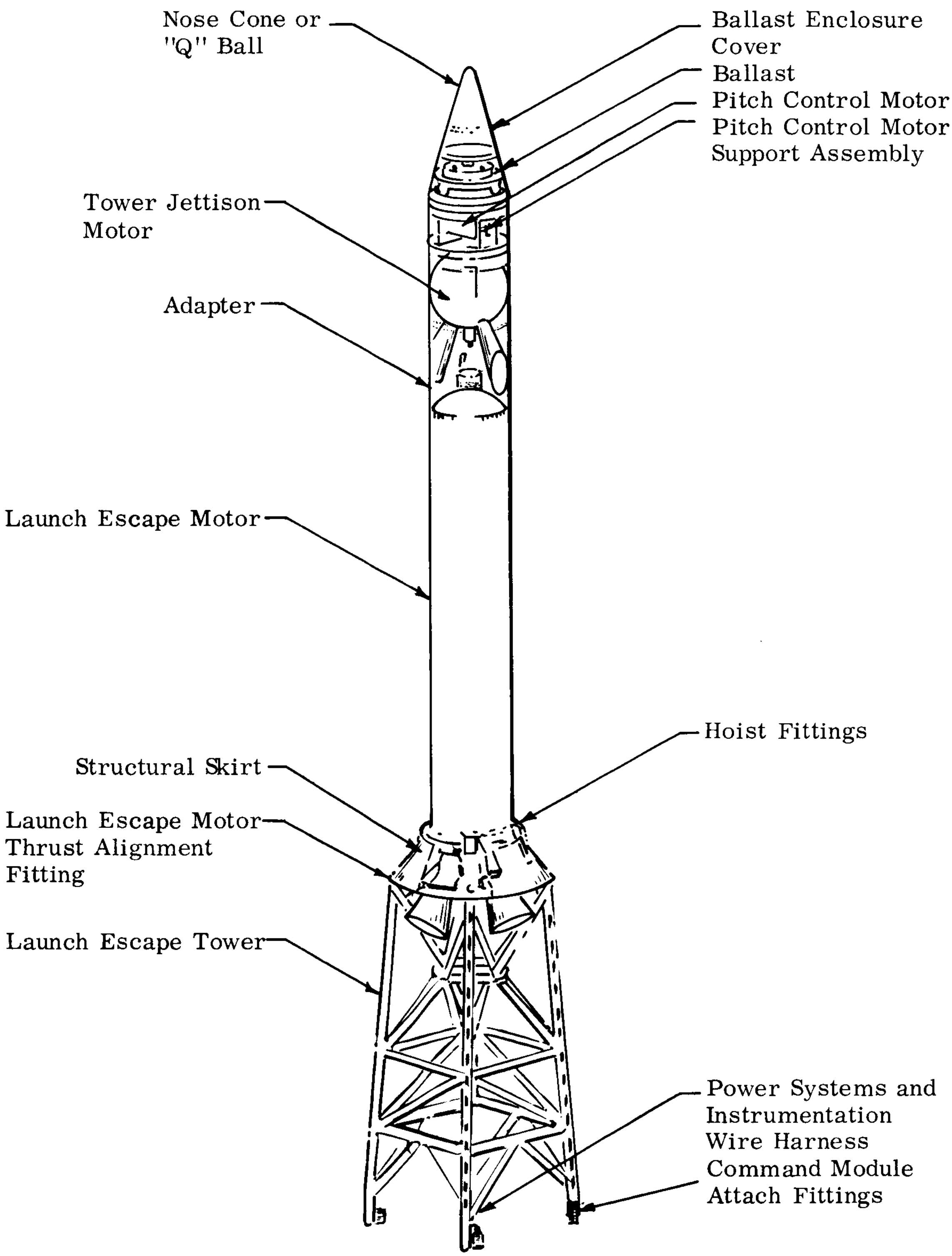
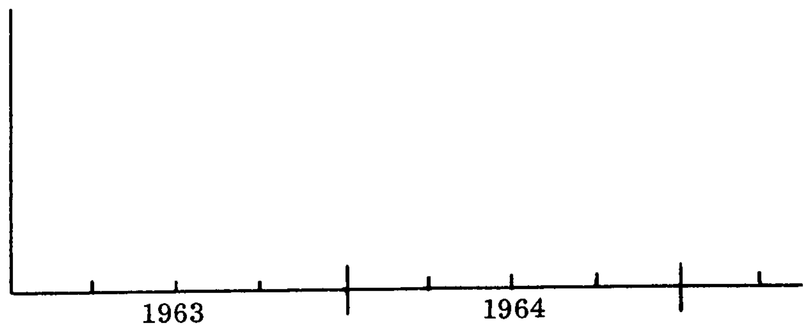


Figure 20-2. Launch Escape System

Launch Escape System Propulsion

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Industry		Notes
		Allocated	Predicted	Achieved	Best	Average	
Engine system	001	0.998	0.993				1
Ignition	051	0.999	0.999				1
Vector Control	021	0.999	0.9992				1
Ordnance	061	0.99999	0.999999				1

Notes:

1. NAA Information.
2.
3.
4.

LAUNCH ESCAPE SYSTEM PROPULSION (CODE: 03 09 01)

FUNCTION

The primary function of the launch escape system is to separate the command module from the launch vehicle in the event of failure or imminent failure. The system will be required to perform the escape function prior to or shortly after liftoff and at maximum dynamic pressure. For normal flights, separation is effected by the main propulsion motor during early operation of the second stage of the launch vehicle.

The basic propulsion system is a solid-fuel motor with step, or regressive, burning characteristics. Its nozzles are canted to avoid direct impingement of the exhaust jets on the command module. The launch escape system is jettisoned at approximately maximum altitude after pad escape, or an appropriate time after maximum dynamic pressure escape, and is separated from the command module by a solid-fuel rocket motor.

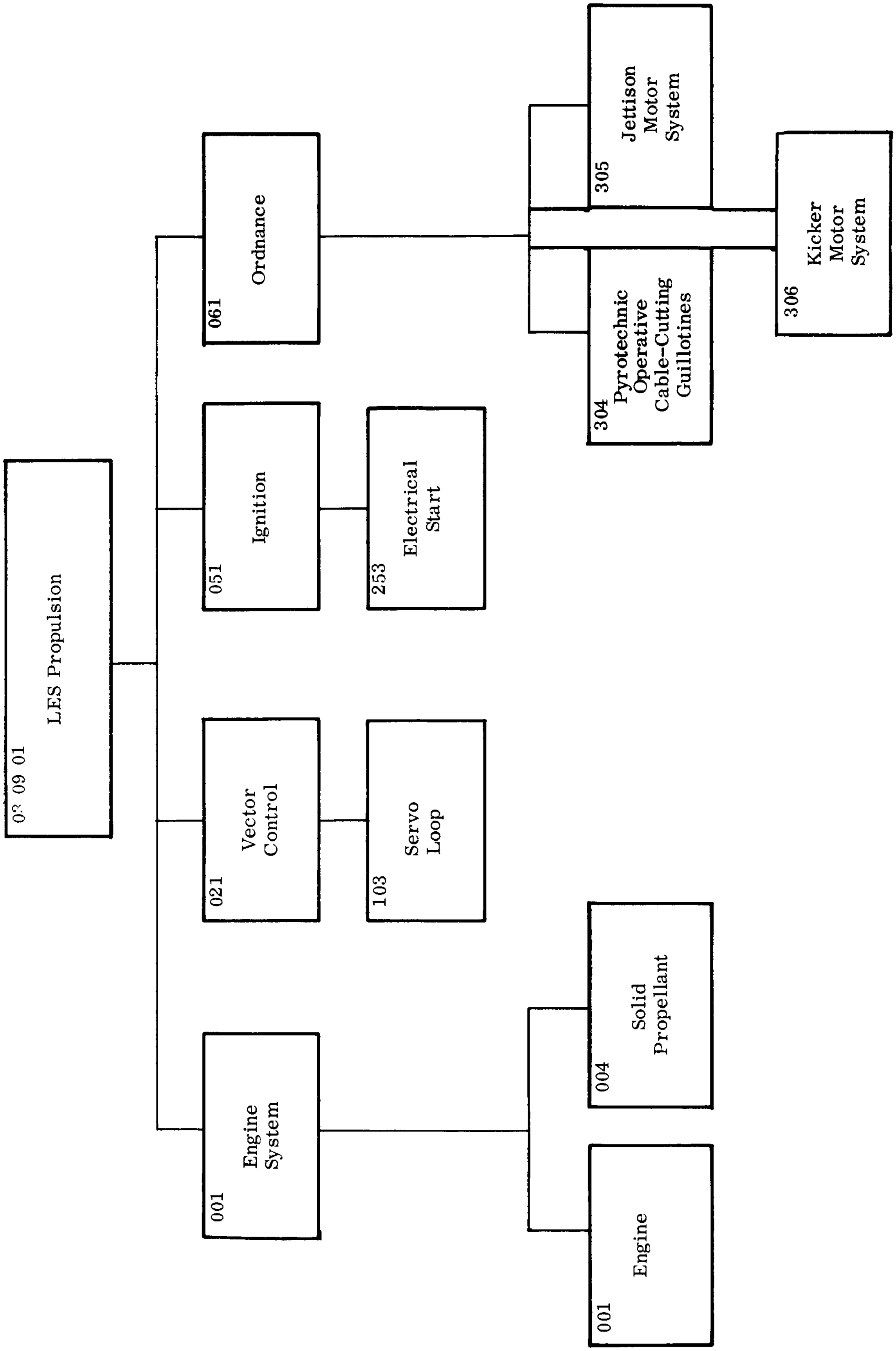
The thrust-vector control will be an integral part of the launch escape motor. The launch escape system control will provide outputs to activate the service module-command module separation initiator, tower separation mechanism initiator, escape motor ignition, tower jettison motor ignition, thrust-vector control initiator, telemetry signals, and recovery system initiators. Circuitry will be redundant. (See Figure 20-3.)

CONTRACTORS

MAJOR CONTRIBUTORS TO UNRELIABILITY

RELIABILITY TRENDS

Launch Escape System
Propulsion



RELIABILITY DOCUMENTATION

Functional Subsystem: Launch Escape System Propulsion (Code: 03 09 01)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis (Partial)	May, 1963	
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments	May, 1963	
9. Reliability Model	May, 1963	
10. Quarterly Reliability Reports	May, 1963	
11. Test Results		X

SECTION 21

GROUND OPERATIONAL SUPPORT SYSTEM

Ground Operational Support System Description

RELIABILITY: Allocated <u>●</u> Predicted <u>o</u> Achieved <u>x</u>

RELIABILITY

Subsystems	Code	Center Submittal			Percent of Unreliability Contributed	Notes
		Allocated	Predicted	Achieved		
Communi-cations	06					
Guidance	05					

Notes:

1.
2.
3.
4.

SECTION 21

GROUND OPERATIONAL SUPPORT SYSTEM
(CODE: 03 10)

DESCRIPTION

Over-all control of all Apollo support elements throughout all phases of a mission will be accomplished from a Mission Control Center (MCC). Mission launch activities up to the time of liftoff will be conducted from a launch control center at Cape Canaveral. In addition to the launch control center, two types of remote stations will be used. The first type of station will provide support for the following communication: voice, telemetry reception and data processing, data transmission from the ground to the spacecraft, tracking to determine spacecraft position and velocity with appropriate data processing and an acquisition system for antenna pointing. The second type of remote station will be equipped for use in tracking the command module during re-entry. These stations will be located both on land and on ships. The remote stations will be connected to the communications and computation centers located in the Mission Control Center by landlines, submarine cables, and/or by radio depending on the location of the remote stations.

RELIABILITY DOCUMENTATION

Functional Subsystem: Ground Operational Support System (03 10)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Notes:

1.

2.

3.

4.

GROUND OPERATIONAL SUPPORT SYSTEM GUIDANCE (CODE: 03 10 05)

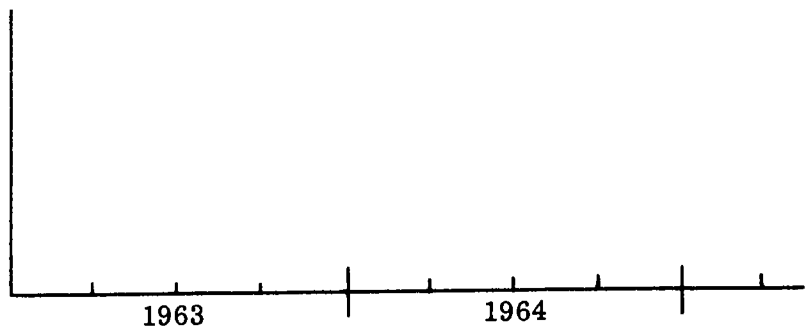
GROUND OPERATIONAL SUPPORT SYSTEM COMMUNICATIONS (CODE: 03 10 06)

SECTION 22

GROUND SUPPORT EQUIPMENT

Ground Support Equipment Description

RELIABILITY: Allocated ● Predicted o Achieved x



RELIABILITY

Subsystems	Code	Center Submittal			Percent of Unreliability Contributed	Notes
		Allocated	Predicted	Achieved		
Propulsion	01					
Structure	03					
Electrical Power	02					
Communi-cations	06					
Guidance	05					
Environ-mental Control	04					

Notes:

1.
2.
3.
4.

SECTION 22

GROUND SUPPORT EQUIPMENT
(CODE: 03 11)

DESCRIPTION

Spacecraft Ground Support Equipment (GSE) includes all the auxiliary equipment, handling equipment, servicing equipment, training equipment, maintenance equipment, and other GSE required to support all configurations of the Apollo spacecraft. These equipment areas encompass all the devices and equipment required to inspect, test, adjust, calibrate, appraise, gage, measure, repair, overhaul, assemble, disassemble, transport, safeguard, record, store, activate, service, maintain, launch, and otherwise support an end article that is associated with the Apollo spacecraft. (See Figure 22-1.)

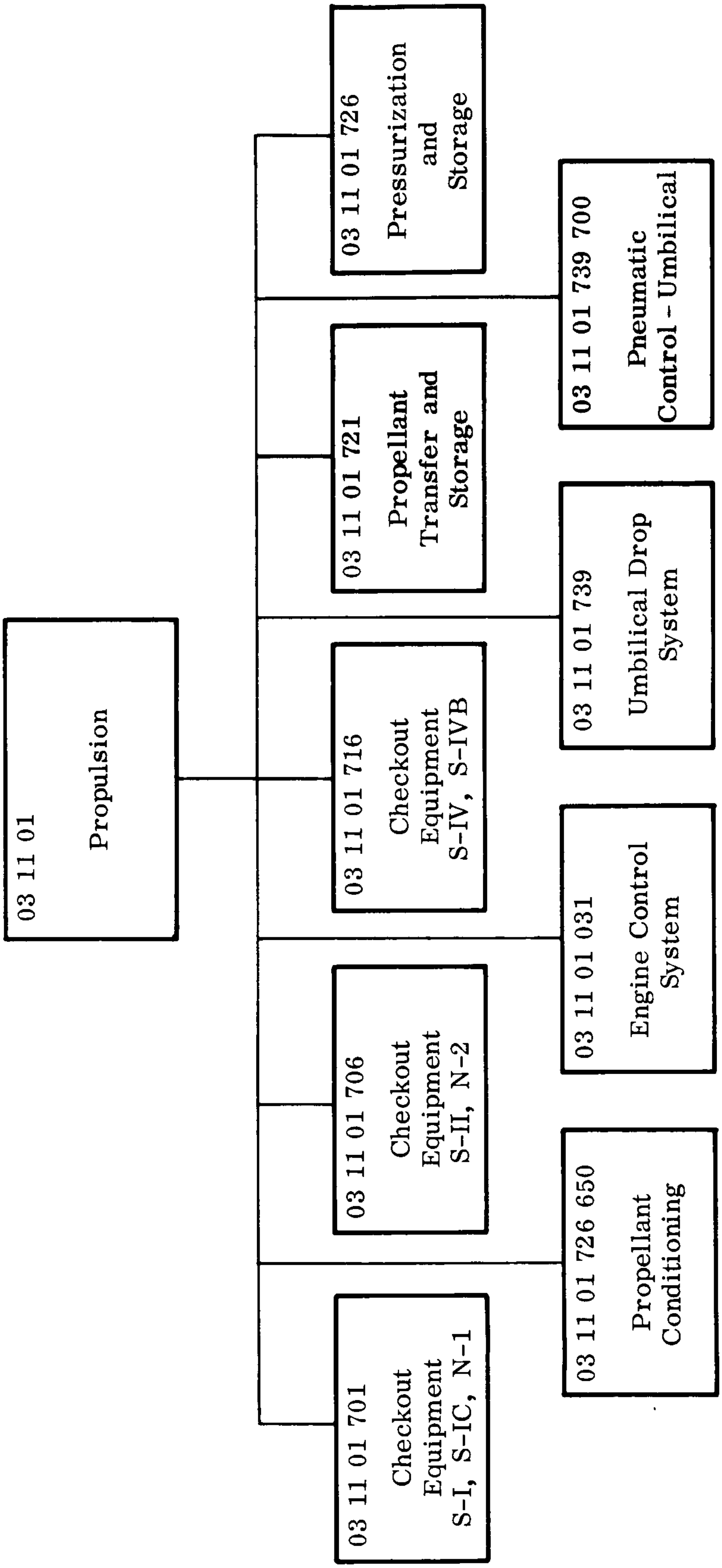


Figure 22-1. Ground Support Equipment Functional Flow Diagram

RELIABILITY DOCUMENTATION

Functional Subsystem: Ground Support Equipment (03 11)

	Center Submittals Received	
	Yes	No
1. Design Specifications		X
2. Top Drawings		X
3. Failure Effect Analysis		X
4. Criticality Analysis		X
5. Performance Analysis		X
6. Structural Analysis		X
7. Maintainability Plan		X
8. Reliability Apportionments		X
9. Reliability Model		X
10. Quarterly Reliability Reports		X
11. Test Results		X

Ground Support Equipment
Propulsion

GROUND SUPPORT EQUIPMENT PROPULSION (CODE: 03 11 01)

FUNCTION

Checkout Equipment

The function of the checkout equipment in the propulsion system of the various flights is to provide an interface that is electrically similar to that of the spacecraft in order to provide a complete functional checkout of the spacecraft's propulsion system (see Figure 22-2). The checkout equipment is divided into three general areas; a computer room, a control room, and a terminal facility. The computer room contains the data acquisition and decommutation equipment, a computer complex, data recorders, and ancillary supporting equipment. The control room contains the primary displays and controls. The terminal facility contains a patching network which provides a terminal for all signal inputs to the checkout station.

Propellant Transfer, Pressurization, and Controls

The transfer unit consists of a pump and control system for transferring propellant from ground storage tanks to the spacecraft, and for returning the oxidizer from the spacecraft back to the ground storage tanks. The transfer unit controls and instrumentation are module type and panel mounted.

Umbilical Propulsion System and Pneumatic Controls

The function of the umbilical propulsion system is for use as a coordinated connection pattern for the propulsion service facilities of the spacecraft. The system contains the necessary disconnects in a pattern which mate with the vehicle connection pattern. Fluid disconnects are self sealing.

Contractors

Contributors to Unreliability

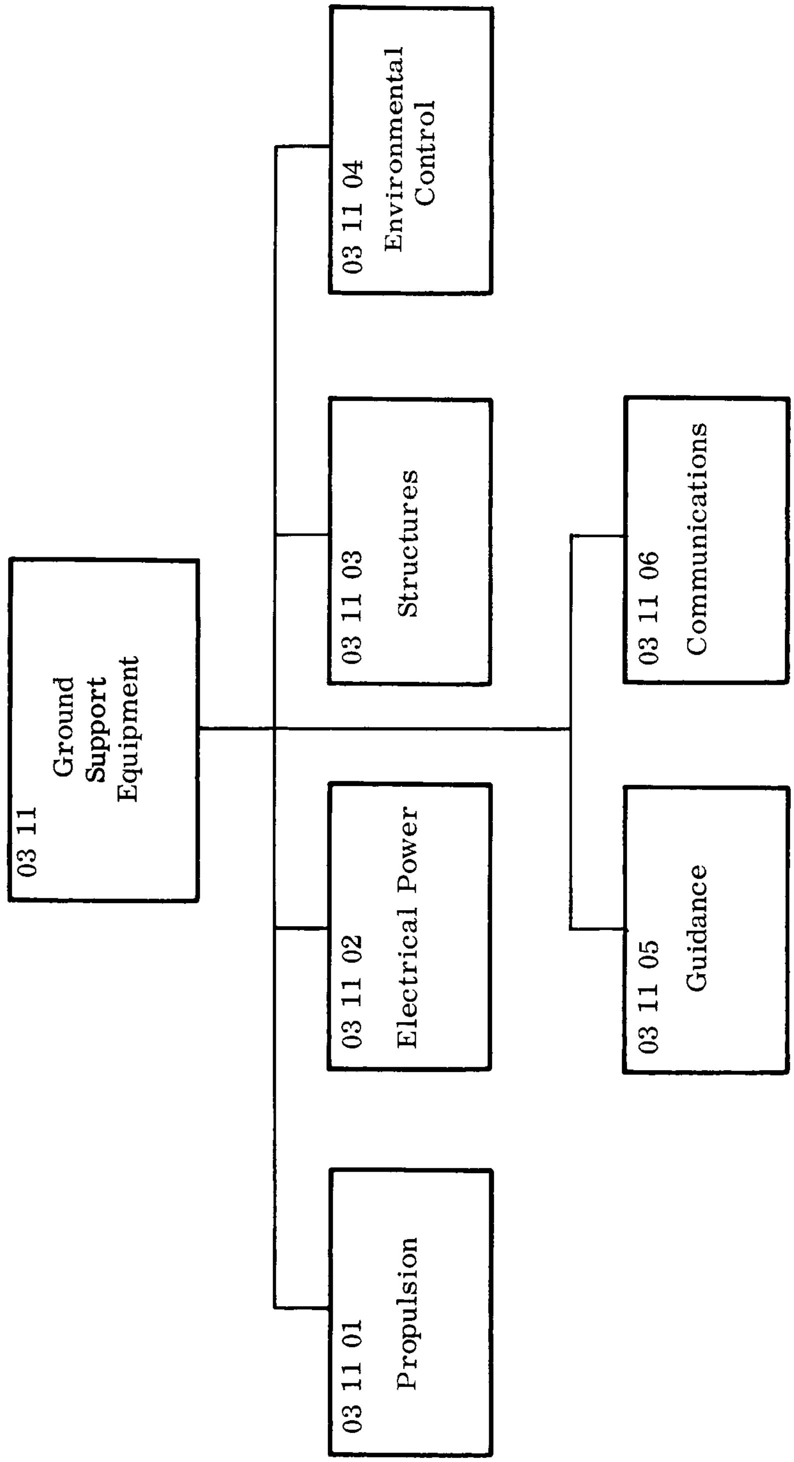


Figure 22-2. Equipment Propulsion System Functional Flow Diagram

Ground Support Equipment
Electrical Power

GROUND SUPPORT EQUIPMENT ELECTRICAL POWER (CODE 03 11 02)

See Figure 22-3.

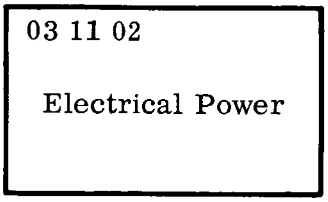


Figure 22-3. Ground Support Equipment Electrical Power Functional Block Diagram

Ground Support Equipment
Structures

GROUND SUPPORT EQUIPMENT STRUCTURES (CODE: 03 11 03)

See Figure 22-4.

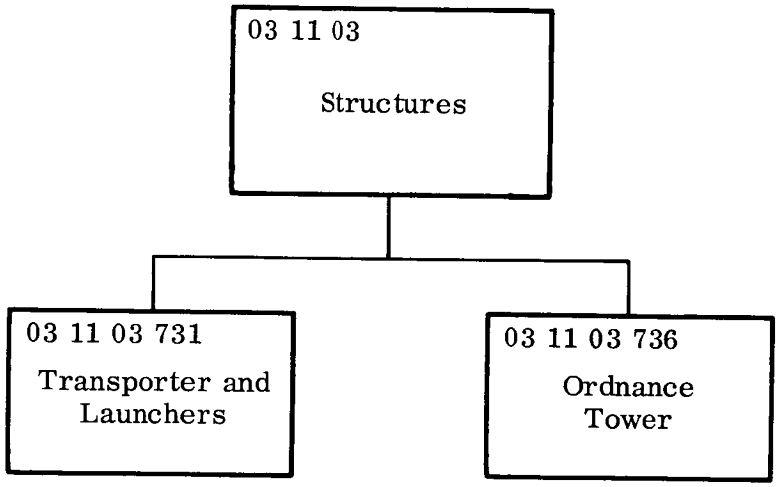


Figure 22-4. Ground Support Equipment Structures Functional Block Diagram

GROUND SUPPORT EQUIPMENT ENVIRONMENTAL CONTROL (CODE: 03 11 04)

See Figure 22-5.

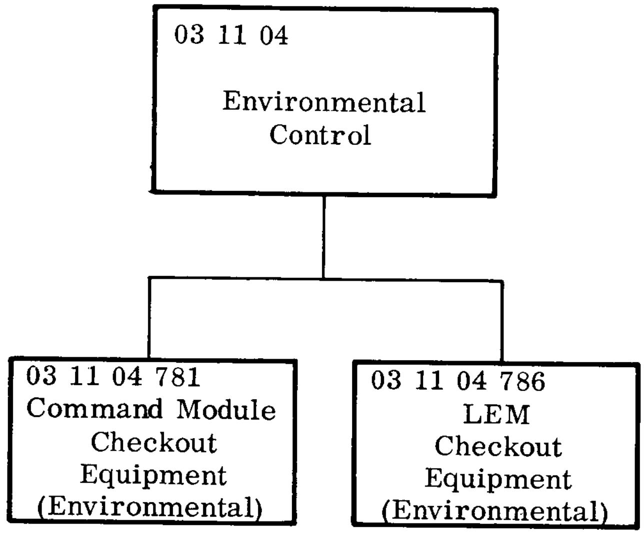


Figure 22-5. Ground Support Equipment Environmental Control Functional Block Diagram

Ground Support Equipment
Guidance

GROUND SUPPORT EQUIPMENT GUIDANCE (CODE: 03 11 05)

See Figure 22-6.

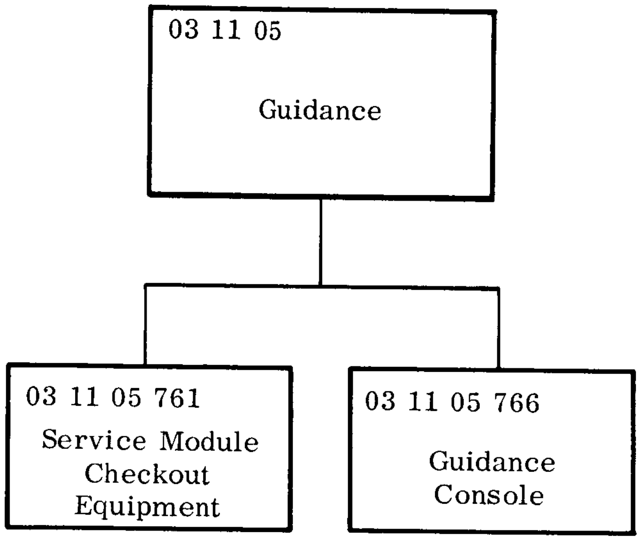


Figure 22-6. Ground Support Equipment Guidance Functional Block Diagram

GROUND SUPPORT EQUIPMENT COMMUNICATIONS (CODE: 03 11 06)

See Figure 22-7.

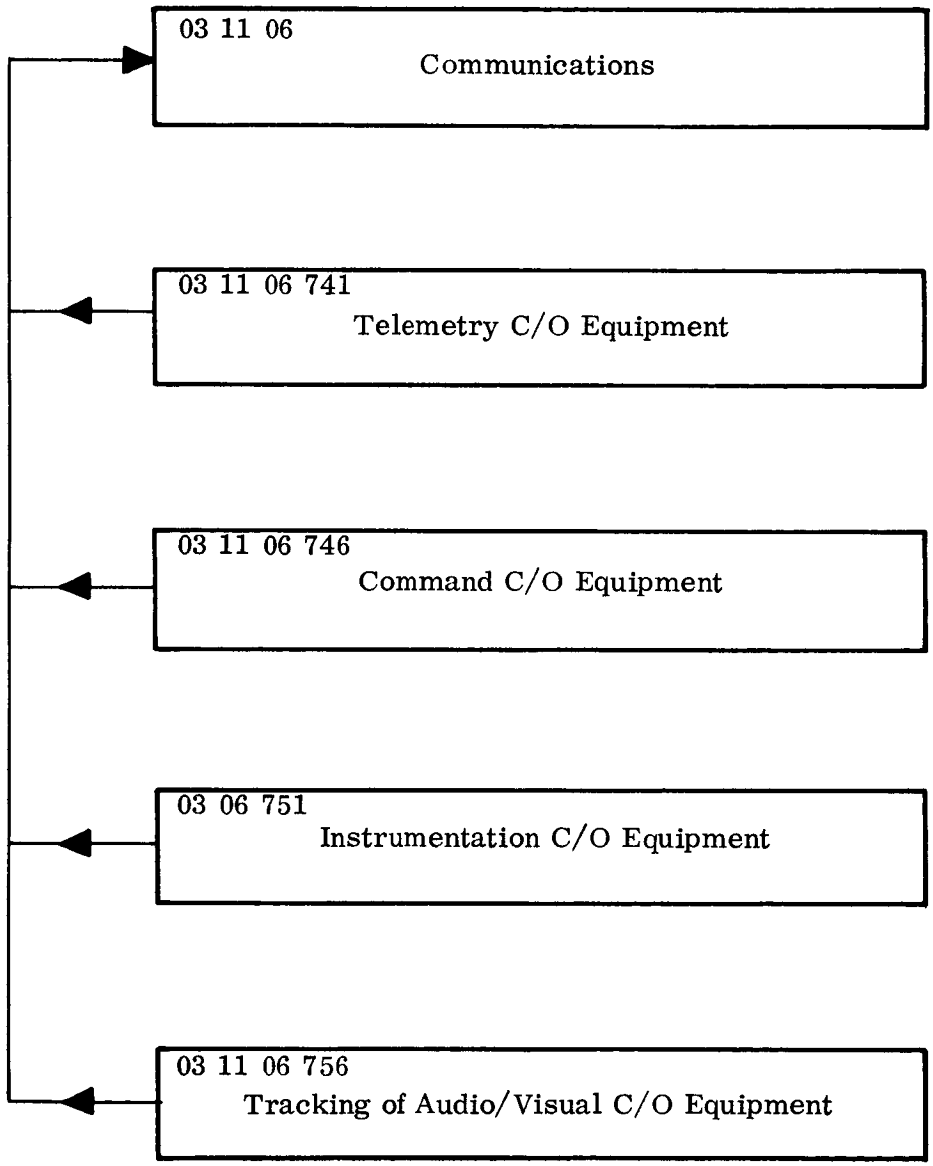


Figure 22-7. Ground Support Equipment Communications Functional Block Diagram